The Student's Handbook to the Microscope

A QUEKETT CLUB-MAN

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THE STUDENT'S HANDBOOK

TO

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BY THE SAME AUTHOR.

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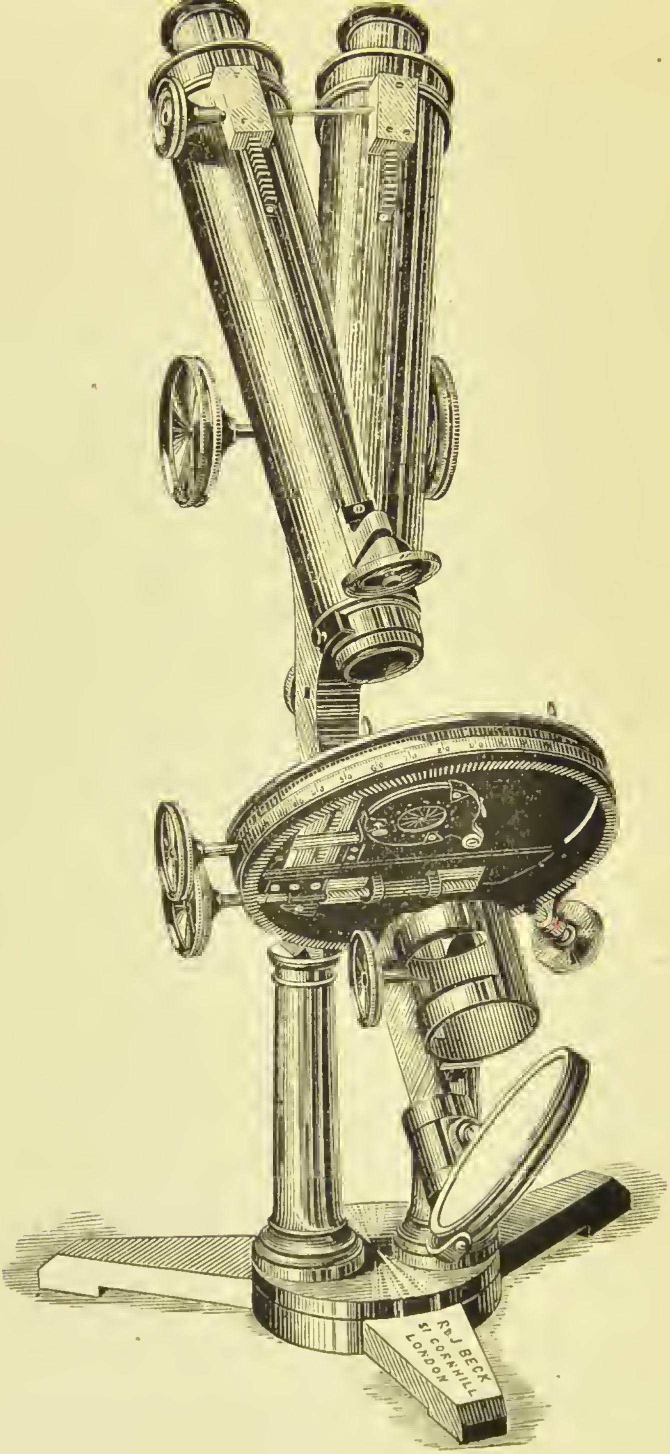

BECK'S FIRST CLASS MICROSCOPE.

87968.

THE STUDENT'S HANDBOOK

TO

THE MICROSCOPE:

A PRACTICAL GUIDE

TO

ITS SELECTION AND MANAGEMENT.

BY

A QUEKETT CLUB-MAN,

AUTHOR OF ‘MY MICROSCOPE, AND SOME OBJECTS FROM MY CABINET.

LONDON:
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PREFATORY NOTE.

In adding one more to the many existing Manuals on Microscopy the author would at the outset disclaim all idea of competition with those already published. So far as he is aware, there is no English volume, except technical manuals, exclusively devoted to an explanation of the *instrument* and description of the uses of its various adjuncts, and he is decidedly of opinion that the collection, preparation and mounting of objects is a separate study, and demands a volume to itself.

Such magnificent and exhaustive treatises as those by the late Dr. Carpenter and Dr. Lionel Beale are, of course, little short of encyclopædias on the subject, and it would be presumption on the part of the author to make further reference to them than an acknowledgment of his indebtedness to the stores of information they contain.

THE STUDENT'S HANDBOOK TO THE MICROSCOPE

CHAPTER I.

THE WORK OF THE MICROSCOPE, AND HOW IT DOES IT.

THE superb instrument which the combined skill of the observer, the optician, the mathematician, and the mechanic has placed in our hands may be said to perform but one function ; namely, to bring our eyes closer to the object to be investigated.

The normal focal distance of unaided vision may be roughly stated as ten inches from the object ; at this interval we can usually obtain the clearest and best view of, say, a page of printed matter. If our eye could approach it to five inches' distance, we should see each letter twice the size we found it at ten inches ; but at such an interval the unassisted eye is unable to gather in the refracted rays to a focus, and indistinct vision is the result, instead of a highly enlarged view of each word or letter.

All microscopes, whether simple (as the common hand magnifier) or compound (with which this volume solely deals), are designed to supply an artificial system of lenses which shall so supplement the human optical system as to enable the observer to see the object as he would do if he could place his eye at an exceedingly short distance from it, and at the same time get clear definition of its details.

Into the laws of optics, and the scientific reasons why an image is formed by an object-glass, the author does not propose to enter; these are fully explained by a score of manuals on optics and light, and would be out of place, or rather superfluous, in a volume which is intended to be an introduction to the use of but one scientific instrument out of the many which are dependent on the same laws for their efficient performance.

When a tyro is placed before a first-rate microscope, either in its case, with all its multifarious and apparently complicated apparatus around it, or set up ready for use, he may well be amazed at the number of appliances required, and feel that here, if anywhere, some guide is necessary who can give needful instructions and explanations. The many appliances which the ever-increasing needs of the observer have called into existence and operation may be classed under three great divisions—those intended to facilitate the presentation of the object to the eye; those designed to properly illuminate it; and thirdly, those whose function it is to assist the observer in the various operations connected with the working of the instrument, such as measuring, drawing, and dissecting the object.

A description of the principal pieces of apparatus appertaining to the microscope for these purposes will be given after the various stands have been alluded to, and, wherever necessary, the mode of use of these accessories will be fully explained.

It will be readily understood that some very firm and substantial stand, or holder, for the magnifying power is absolutely necessary, as the human hand is quite incapable of holding an object, or a glass, steadily enough for investigation at a distance of $\frac{1}{10}$ of an inch, say, from the eye. This support is furnished by what is called the 'stand,' which serves to hold the 'object' to be viewed, and supplies a tube or tubes in which the magnifying powers are held, the whole forming a very perfect optical instrument, only needing the application of the human eye to the top of the tube to complete it as 'the most accurate and the most marvellous of modern scientific instruments.'

An examination of some of the patterns of stand furnished by first-class makers will give an excellent idea of the perfection which has been attained in their production, and of the exquisite care and forethought which have in many cases anticipated wants before they have arisen, and provided facilities for investigation which but twenty years ago, or less, would have been deemed impossibilities.

It should be scarcely necessary to remark here that magnification is only one portion, and a minor one, of the work of the microscope: it would be of small service if it would only show us what we could see with the naked eye, on an exaggerated scale; but the principal province of the instrument is to reveal to us minute detail which is partially or totally invisible to the unassisted vision.

THE VARIOUS PARTS OF A MICROSCOPE STAND.

THE STAND proper is the entire frame or carriage used for holding the object to be examined, the machinery for presenting it to the eye, and the whole of the optical and illuminating apparatus.

THE FOOT is the lower part of the stand touching the table on which it rests, and should preferably come in contact with whatever it rests on at only three places—the maximum of steadiness is then secured.

THE BODY is the tube (or tubes if the instrument s binocular) which contains the eye-piece at the upper end, and the object-glass at the lower.

THE LIMB is that part of the frame to which the ody is attached.

THE STAGE is the plate upon which is placed the object for examination; it may be of many various patterns. In the simpler cases it simply supports the object, which has to be moved about by the fingers to bring its various parts into view; in more complex stages mechanical arrangements are provided by which motion is produced with great nicety.

THE EYE-PIECE is the double lens placed next the eye of the observer at the top of the body; the glass nearest the eye is called the eye-glass, and the one farthest from it the field-glass: these are separated by what is called a diaphragm, or sheet of metal with a central perforation.

THE OBJECT-GLASS is the lens, or system of lenses, placed in the bottom of the body, and is the most important and the most expensive of the optical portions of the microscope. From two to twelve object-glasses may be required for the complete equipment of a first-rate instrument, and as it is not too much to say that the highest optical skill is employed in their production, it is, of course, a necessity that their cost is in proportion. The lowest powers are the cheapest, as less skill and delicacy are employed in their manufacture, as well as fewer lenses in the combination which makes up the 'glass'; but the higher powers when furnished by first-rate makers are very expensive luxuries, £15 to £25 being ordinary prices for some of highest power and quality.

THE COARSE ADJUSTMENT is the rack and pinion, worked by a milled-head on each side of the body, which raises or depresses the tube, and brings an object into focus roughly—in most cases, with low powers in use, quite accurately enough, but when using objectives of half an inch focus, or higher, some more delicate mode of focussing is required; this is supplied by the following.

THE FINE ADJUSTMENT is variously placed in different patterns of stand, but consists of a single milled-head attached to a very finely threaded screw, which moves either the lower part of the body or the whole of it in the same direction as the coarse adjustment, but with an infinitely slower motion.

THE MIRROR is the reflector placed below the stage, in the best stands usually hung on a jointed arm. It is the source of light for investigation of all transparent objects, and should have two surfaces, one plane and the other concave, each of which has advantages in special cases.

THE SUB-STAGE is fitted underneath the main-stage or platform in high-class stands; various mechanical motions are usually applied to it, its chief functions being to hold and adjust the various pieces of apparatus used under the stage for the better illumination or exhibition of objects; these have to be dispensed with in instruments unprovided either with a substage or substitute in the shape of a circular fitting under the primary platform.

THE BINOCULAR ARRANGEMENT. — For instruments having two tubes, and used by both eyes at once, a small prism—called, after its inventor, 'the Wenham prism'—is inserted in the nose of the instrument as near as possible to where the objective is screwed in; this prism directs one half of the image-producing rays passed by the object-glass, into the left-hand tube, so that both eyes can be employed in observing it. The binocular is especially valuable for the examination of objects of some size by the lower powers of the instrument, the stereoscopic effect produced being very striking, and conveying a far more distinct idea of a 'solid' object than the monocular is capable of. It is, however, unsuitable for use with higher powers, under ordinary conditions, than the ½-inch; but when more powerful glasses are necessarily in use, the withdrawal of the prism instantly converts the binocular into a monocular, and leaves the right-hand tube free for the passage of the whole of the rays transmitted by the object-glass.

CHAPTER II.

FIRST-CLASS MICROSCOPE STANDS.

THE following four instruments have been chosen as types of microscopes of the highest quality, finish, and capacity.

In their production has been spared neither skill nor cost, the aim in view being the provision of an instrument which shall be capable of performing anything that a microscope can be expected to accomplish.

To these stands can be adapted and easily applied all or any of the accessory apparatus described at length in this volume, thereby rendering the instrument complete for any class of investigation.

The object in their construction has not been simplicity, but perfection, and the author would remark that the complexity in some of the stands is by no means so great as would appear at first sight: the hand of the observer is easily trained, and without removing his eye from the tube, he quickly learns to find, as it were by instinct, the milled-head or other portion of the mechanism he wishes to use, while the facilities afforded by such microscopes as these enable the observer to use appliances which are not workable in instruments of smaller size or less perfection of manufacture.

BECK'S LARGE FIRST-CLASS STAND.

(*Frontispiece.*)

In this very high-class instrument will be found every mechanical adjustment that can be required by the most exacting observer.

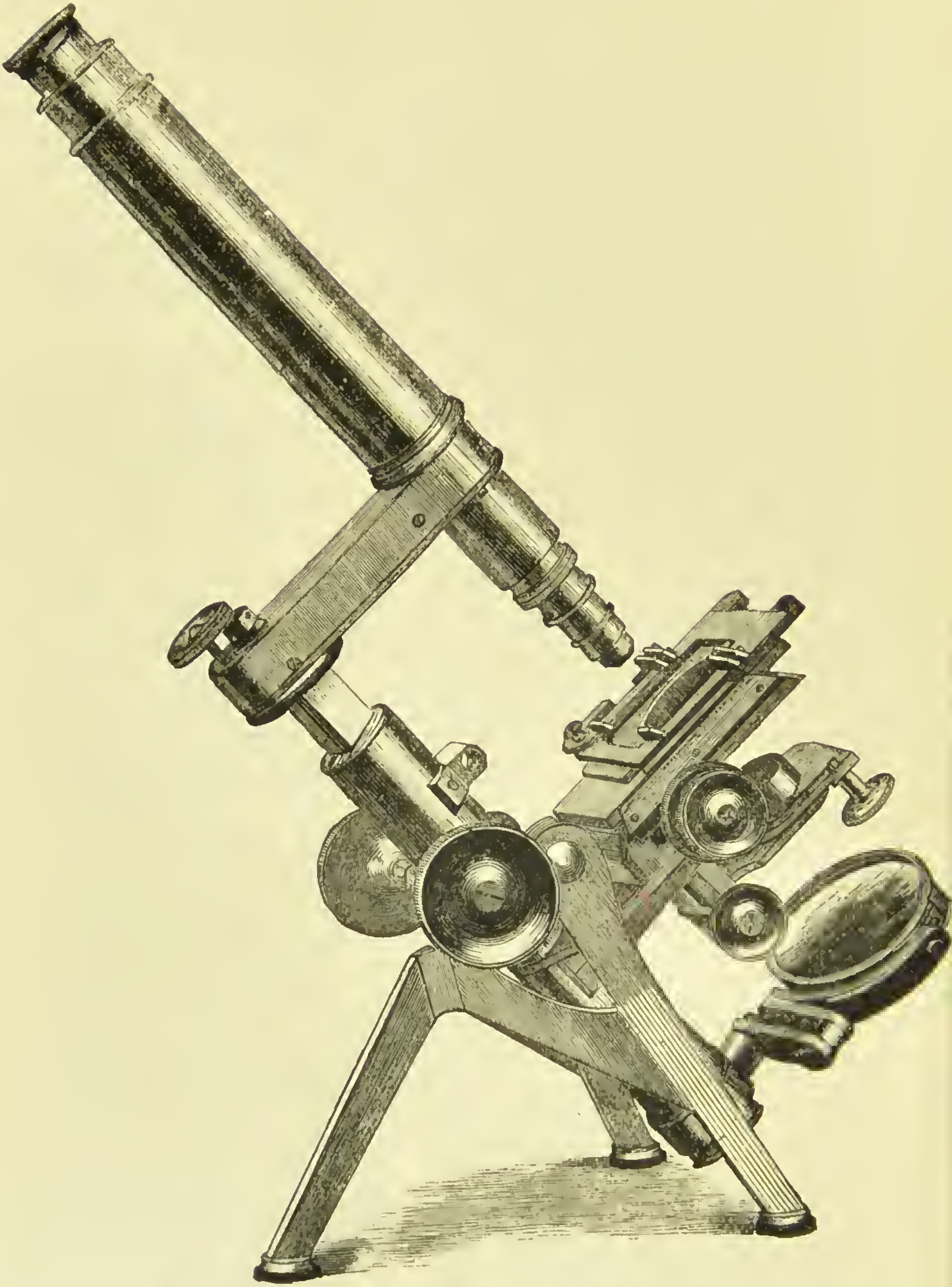
It is, like all the first-class stands of this firm, constructed on the Jackson model, the body being supported along the greater portion of its length by a limb, which gives great support and steadiness to the optical tubes.

The stage is graduated on its edge to 360° ; it rotates, either mechanically or by the hand, concentrically with the optic axis of the instrument, and it is moved in lateral directions by the usual milled-heads.

The sub-stage, in the form shown, is not provided with rotating motion, but has rack and pinion focussing adjustments.

The mirrors (plane and concave) are of large size, and so mounted as to be able to reflect light of the greatest obliquity through the wide opening of the main-stage, when the very ingenious 'Iris diaphragm' with which the latter is furnished is removed. The whole instrument is suspended between two solid pillars, which stand on a firm base which rests on the table at only three points.

The cost of this stand complete, with 'Iris diaphragm' and two pairs of eye-pieces, is, in binocular form, £35; if monocular, with two eye-pieces, £28.



Messrs. Powell and Lealand's 'No. 2' Microscope Stand.

MESSRS. POWELL AND LEALAND'S 'NO. 2' STAND.

This fine instrument is constructed on the pattern called the 'bar movement,' having the optical tube unsupported along its length : this model was formerly used by Messrs. Ross, who have, however, of late largely favoured the Jackson pattern in their highest-class stands.

Excellent workmanship in the stand under notice ensures freedom from tremor, and stability in whatever position it may be placed.

It will be noticed that a very wide spread is given to the legs of the tripod so as to further this most desirable end.

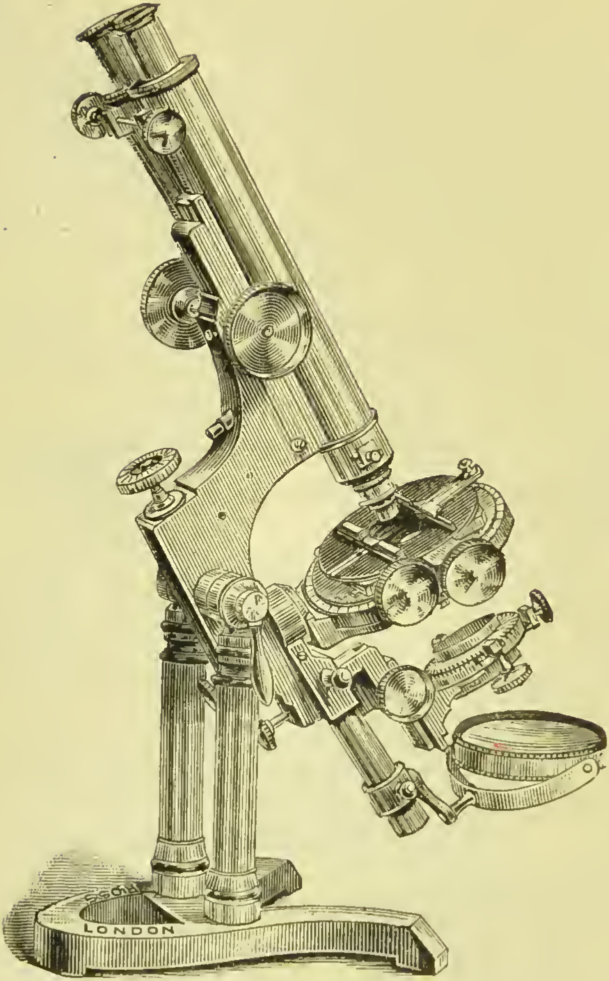
The stage has ¾ inch of motion in rectangular directions, and is moved by two milled-heads both working on the same axis ; it also rotates by hand.

A sliding and rotating object-holder is also furnished.

The sub-stage has full mechanical motions, both rotary and rectilinear, and the large mirrors are most conveniently mounted on a double crank arm.

In this microscope are combined the perfection of mechanism and great simplicity of construction.

The price of this stand in its monocular form is £28 ; this includes two eye-pieces.



ROSS'S PATENT 'NO. 1' BINOCULAR STAND.

Ross' Patent 'No. 1' Binocular.

This very high-class stand is made on the Jackson model; that is, the body is supported along the greater portion of its length by an extension of the limb, giving the greatest possible steadiness and freedom from vibration.

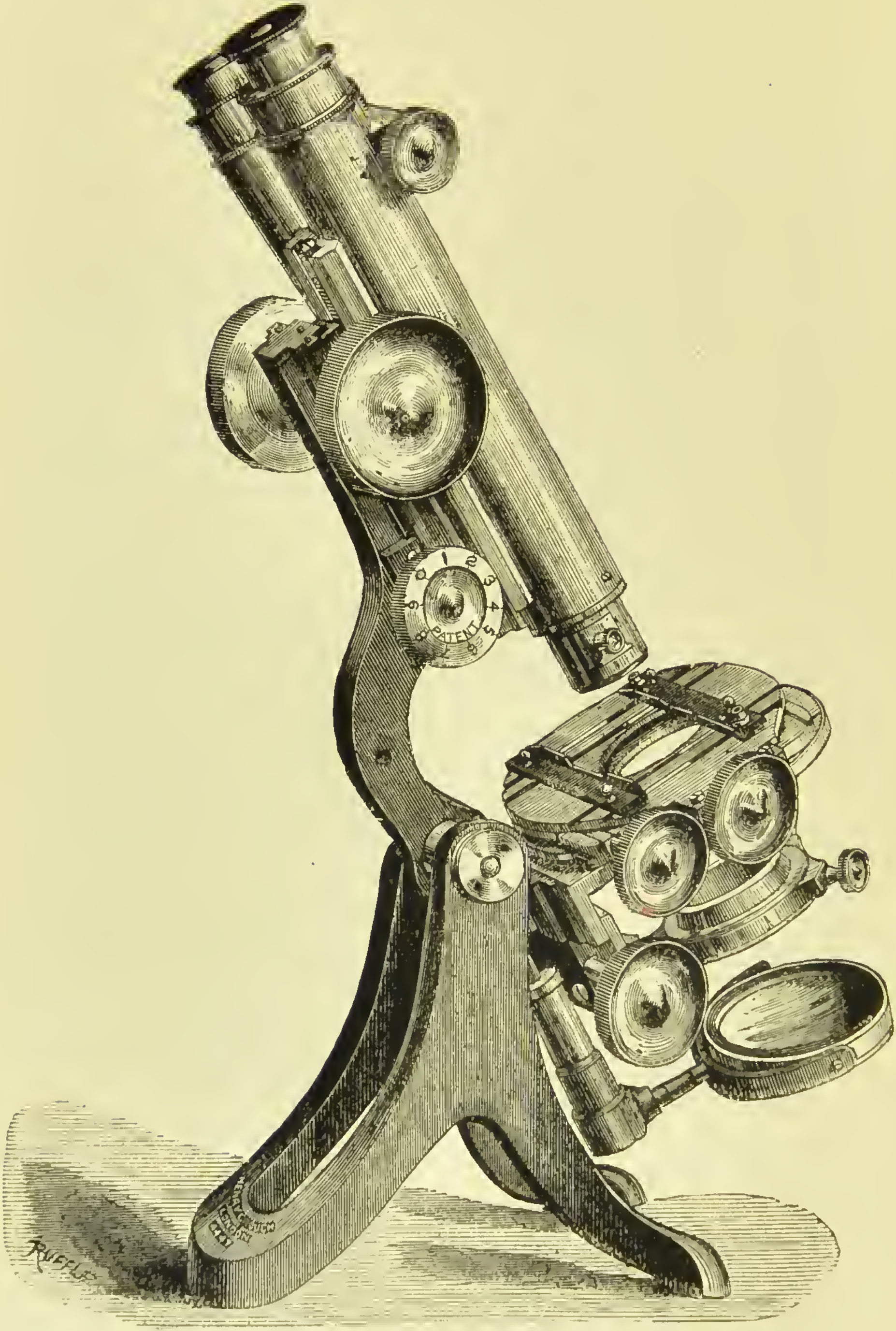
The workmanship of this instrument leaves nothing to be desired; everything is of the highest quality and finish.

The main-stage is graduated on its outer edge to 360° for measurement of angles of crystals, and for use when polarized light is employed; the motions to it are conveyed by rack and pinion, and it has concentric motion in the optic axis; a clamp is attached to the trunnion to fix the instrument at any angle.

The sub-stage has complete adjustments in lateral directions, as well as full focussing arrangements: it also rotates mechanically.

The double mirror, besides being mounted on a crank arm, is suspended on Zentmayer's swinging tail-piece.

The cost of this stand as a binocular, with a single pair of eyepieces, is £33 5s.; in its monocular form, £28.



CROUCH'S IMPROVED 'PREMIER BINOCULAR MICROSCOPE.

CROUCH'S IMPROVED 'PREMIER' BINOCULAR.

This stand, although of rather small size (15½ inches when upright and tube racked down), is well worthy of being classed among first-class instruments.

It has recently been remodelled, and all really essential improvements adapted to it. The coarse adjustment is so delicate that an objective of as short focus as ⅙ inch can be accurately focussed by it, and the fine motion is communicated by a new patent arrangement ensuring absolute steadiness, stability and freedom from lateral motion.

The stage is extremely thin, and its wide opening beneath gives all requisite facility for the application of oblique light. It is moved by rack and pinion, and rotates concentrically; the diaphragm is removable, and the sub-stage is hinged for the greater convenience of insertion of the achromatic condenser, paraboloid, etc.: this will be found of great advantage in an instrument of so moderate a size.

The mirrors are double, and have every necessary motion; their size, too, is ample, and they are hung on a swinging arm.

This microscope is supplied in its binocular form for £17 17s., with a 1-inch and ¼-inch object-glass, one pair of eye-pieces and large stand condenser. If monocular, with two eye-pieces of various power, £15 15s.

The sub-stage, with centring and focussing adjustments as shown, adds £2 5s. to the cost in either case.

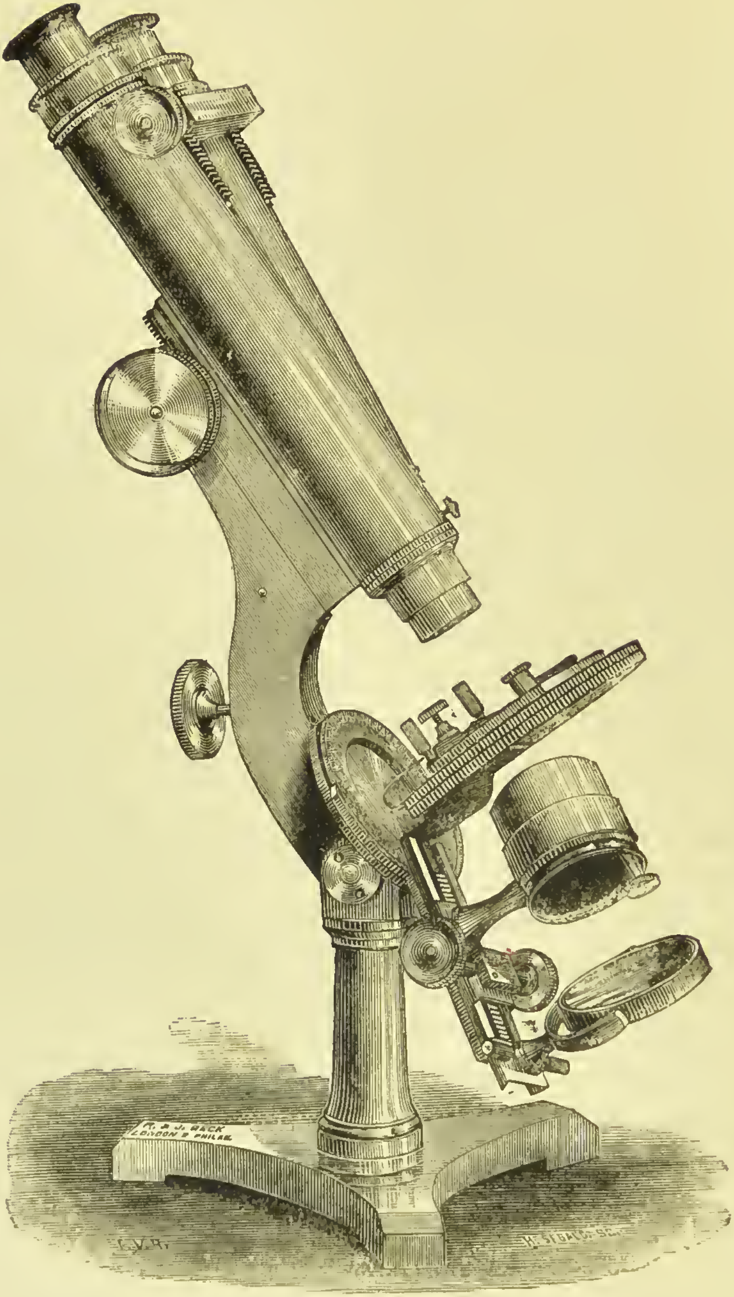
CHAPTER III.

SECOND-CLASS, OR 'STUDENTS'' STANDS.

In the forms of stand next to be described, the workmanship is of the highest quality, but as the desideratum in this class of instrument is efficiency combined with *economy*, the size of the instrument itself is of necessity reduced, and the fittings and adjustments are limited to those only which are found absolutely requisite for scientific investigation.

The demands of the public for this description of microscope have of late years been so largely increased, and the rivalry in their production amongst makers of repute has in consequence been so keen, that it is not too much to say that any one of these 'second-class' microscopes is now superior, both in finish and performance, to what could be purchased for any money, at a distance of time quite within the memory of many living microscopists.

The author would strongly advise the purchasers of these stands, wherever the difference in price is not of serious moment, to combine with them objectives of the first quality: most makers produce object-glasses of two standards, and the more expensive are in nearly all cases the cheaper in the end.


R. & J. BECK
LONDON & PHILAD.
E.V.R.
H. SEBALD SC.

BECK'S 'NATIONAL' MICROSCOPE.

BECK'S 'NATIONAL' MICROSCOPE.

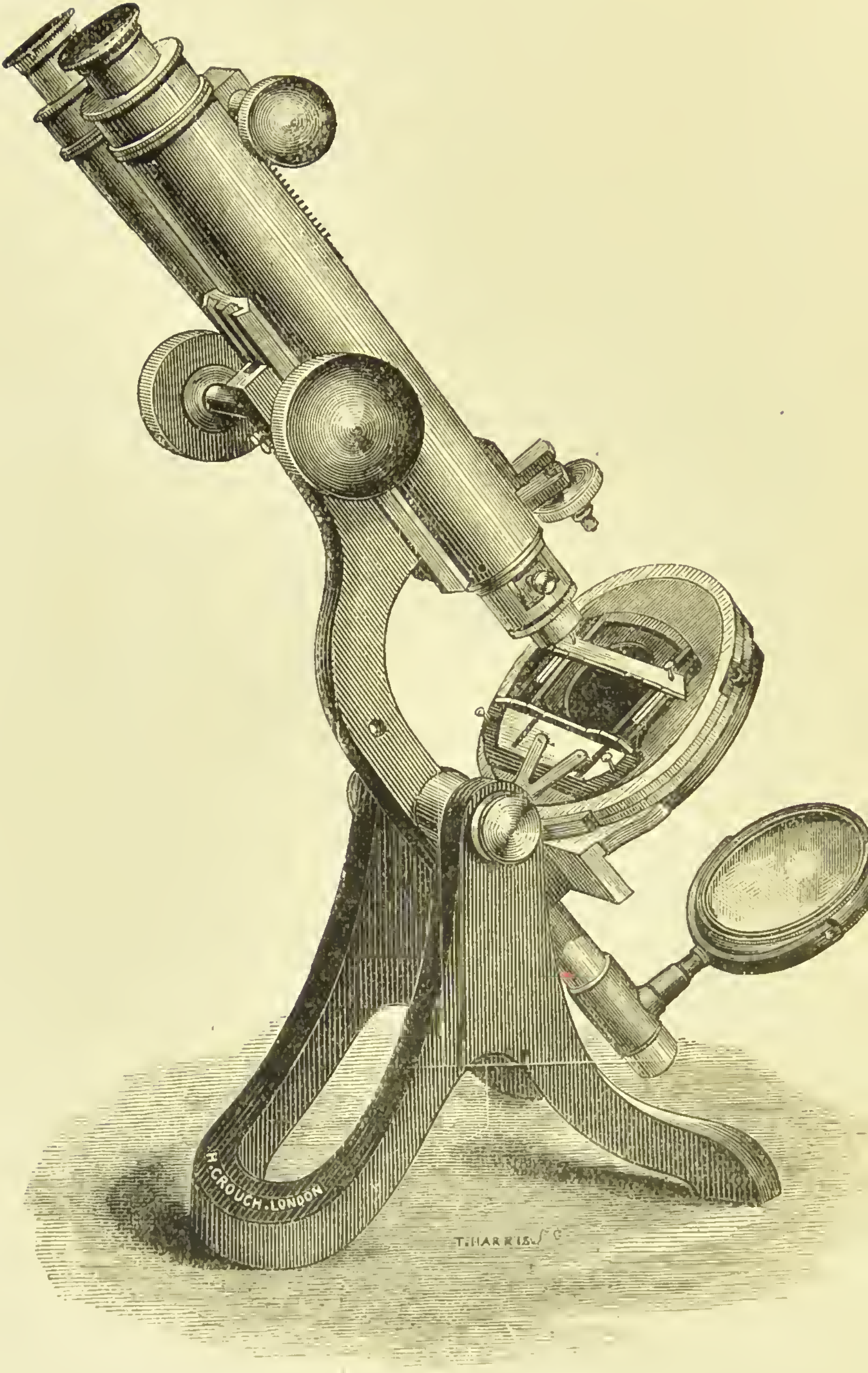
This very convenient stand comprises most of the mechanical adjustments which have hitherto only been found in larger and much higher priced instruments.

As in all microscopes of this firm's manufacture, the workmanship is of high class.

The eye-pieces have rack adjustments to suit varying distances between the eye of the observer. The sub-stage is pivoted in the centre of a divided arc, enabling any desired angle of illumination to be registered for future observation, and has also rack motion for focussing the accessories used in it. The concave mirror is also attached to the same stem.

The price of the binocular stand, as figured, with one pair of eye-pieces and conical diaphragm, is £14 15s.; if monocular, £11 5s.

Objectives and apparatus can be selected to suit the requirements of the purchaser.



CROUCH'S 'STUDENTS'' MICROSCOPE.

CROUCH'S 'STUDENTS'' MICROSCOPE.

The illustration shows this very excellent and convenient stand in its binocular form, but it is also made monocular.

The quick adjustment is made by a spiral rack and pinion movement, and is so delicate that objectives up to $\frac{1}{6}$ inch can be accurately focussed without the aid of the fine motion.

The fine adjustment is of the best construction and of great sensitiveness.

The glass stage is much reduced in thickness and is quite open underneath, giving much greater facilities for oblique illumination.

The object-carrier is greatly improved, the glass sliding plate being mounted in a frame having a sliding clamp for securing the object under examination, and bearing upon three points, ensures great steadiness while traversing the stage.

A hinged sub-stage can be adapted, and is entirely removable by a lateral slide when not required.

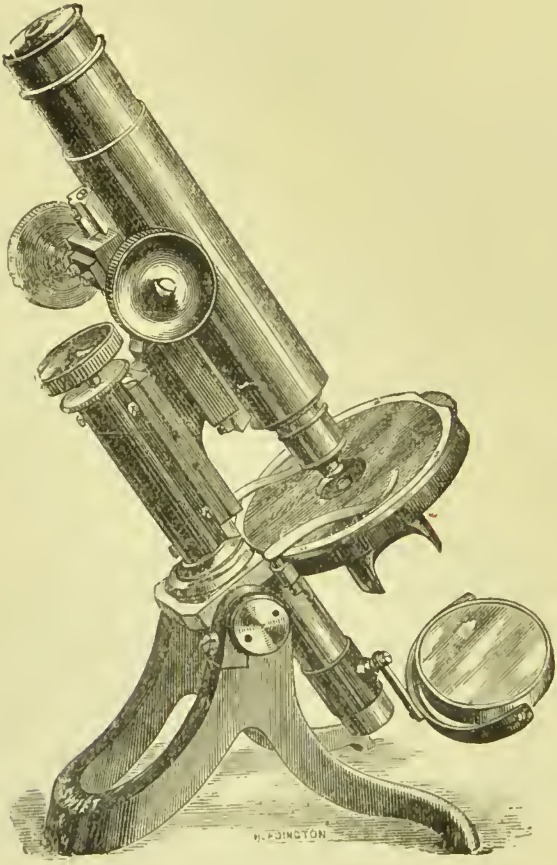
The binocular body is provided with rack and pinion adjustment to draw tubes, to suit the varying distance apart of the eyes of different observers.

The mirrors are extra large, plane and concave, and are fitted to a mirror-stem pivoted at its attachment to limb, for the greater convenience of illuminating objects by oblique light. (This arrangement is not shown in the engraving.)

When the extra cost of a sub-stage is a consideration, the fitting supplied beneath the main-stage is so contrived that it will take all the more important accessories, such as paraboloid, or spot lens, achromatic condenser, and polarizing prism, and either of these can be adjusted by a sliding motion. This microscope is certainly one of the best instruments of its class: as remarked by the late Dr. Carpenter, it is 'at once cheap, good, and portable.'

The price of the monocular form, with two eye-pieces, 1 inch and ¼ inch object-glasses of best quality, large stand condenser, and mahogany case complete, is £10 15s.

If binocular, with one pair of eye-pieces, £12 15s. The after-addition of a hinged sub-stage costs £2 5s. extra.



SWIFT'S 'COLLEGE' MICROSCOPE.

SWIFT'S 'COLLEGE' MICROSCOPE.

A very portable form of stand, well hung on a firm horseshoe foot. The body tube sliding within itself enables the instrument to be packed into a very low case, and it is one of the few efficient instruments known to the author which is at the same time good enough and portable enough to take out for exhibition at a *soirée* or *conversazione.*

It is furnished with a rotating glass stage, which carries two brass clips for securing the mounted object in position.

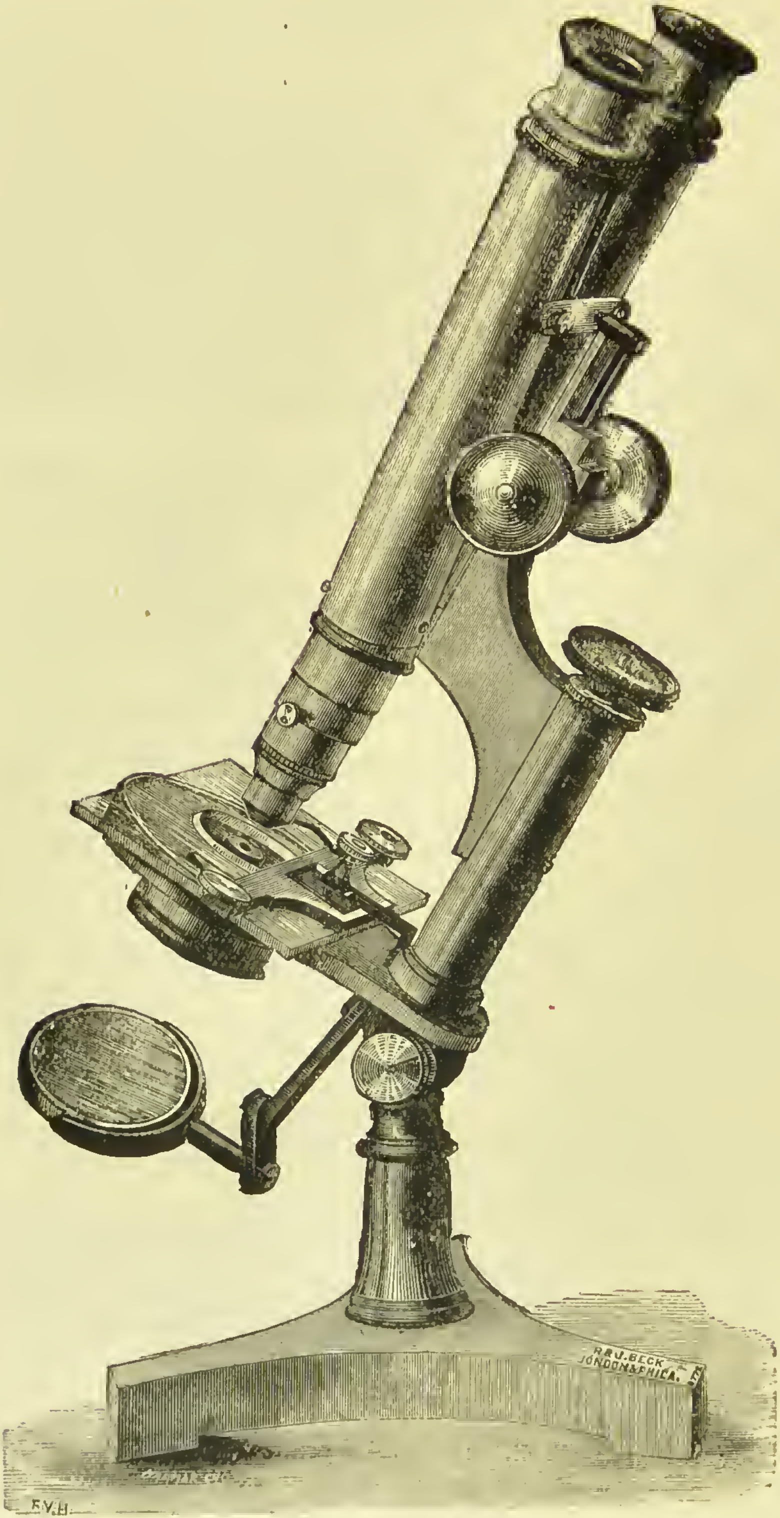
Both coarse and fine adjustments work smoothly and accurately, and the double mirror is conveniently mounted in a semicircle on a crank arm.

The circular fitting below the stage will accommodate the usual accessories, as in Crouch's Students' Stand, and this fitting can be unscrewed whenever the application of extremely oblique light from the mirror only is desired.

The price of this instrument, with a 1 inch and ¼ inch object-glass of good definition, two eye-pieces, a condenser to fix on the stage, camera lucida, etc., in mahogany case, is but £8 2s. 6d. An achromatic condenser, polariscope, and spot lens can be added for an extra £2 14s. which would then constitute this an extremely serviceable microscope.

NOTE.—Excellent students' microscopes of most efficient performance are also constructed by Messrs. Baker, Browning, Collins, Coppock, How, Pillischer, Stanley and Watson.

It may also be remarked that all of these firms produce stands which may be included in the 'first rank': and the necessary limits of such a handbook as this alone prevents individual illustration or description of them. The addresses of all opticians referred to in this volume will be found at the end.


R&J. BECK
LONDON & PHILA.
E.V.H.

BECK'S 'ECONOMIC' MICROSCOPE.

CHAPTER IV.

THIRD-CLASS, BUT GOOD WORKING INSTRUMENTS.

UNDER this heading it is proposed to describe several forms of microscope which, while in most cases not laying claim to be serviceable as instruments for scientific research, are yet of such good construction, both mechanically and optically, that they may fairly be designated 'good working instruments,' and are quite capable of showing satisfactorily the details of a large proportion of the objects usually exhibited and examined under microscopes of much greater calibre and cost.

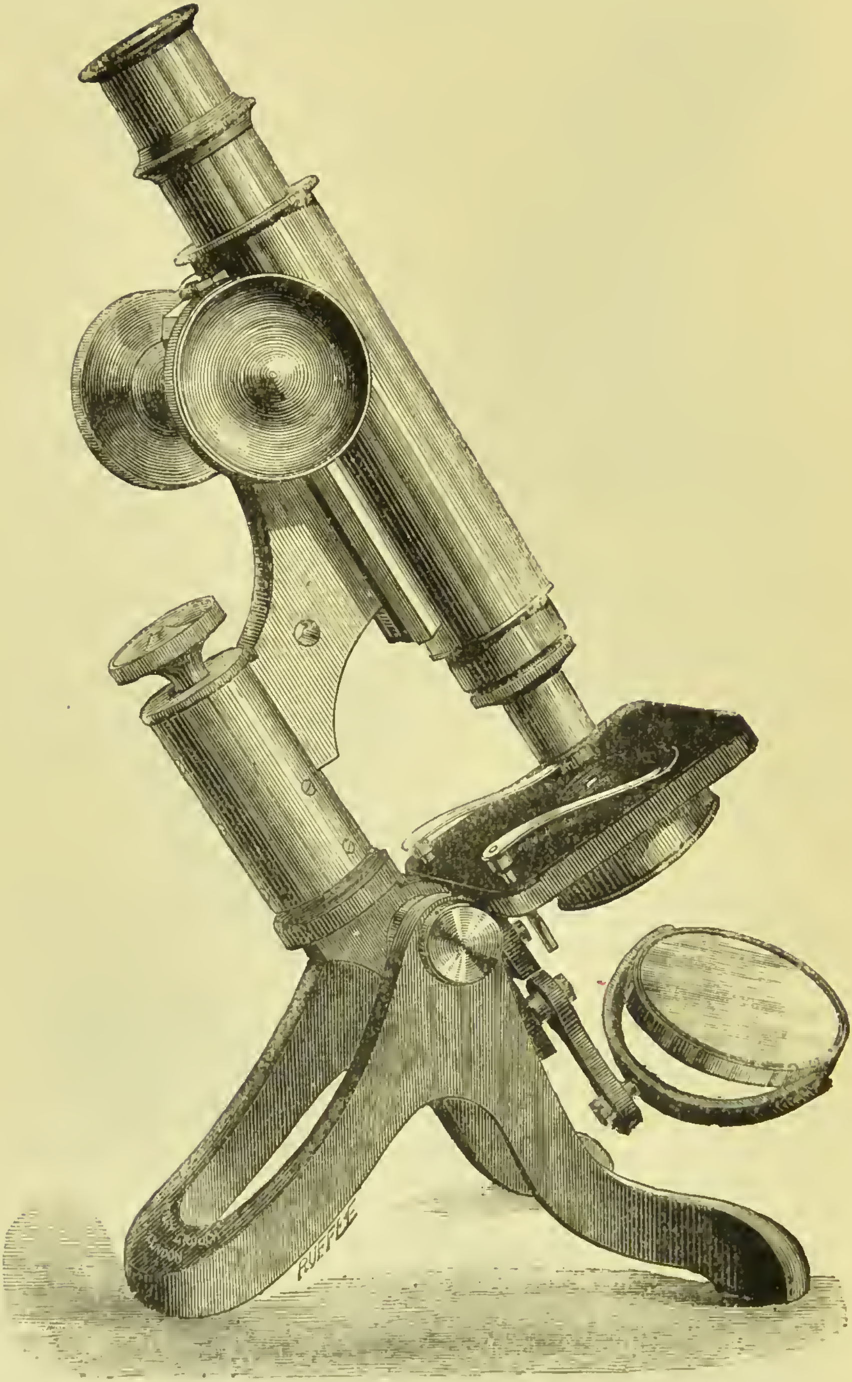
BECK'S 'ECONOMIC' MICROSCOPE.

This is a handy form of stand, very efficient, and cost in its production has been saved by its simplicity of construction rather than inferiority of workmanship.

It has an excellent working glass stage; mirror on a crank arm, and the usual circular fitting for apparatus below the stage. The adjustment to the eye-pieces is made by a 'lift' in place of the rack and screw furnished in larger stands.

It is supplied in binocular pattern, as illustrated, with 2 inch, 1 inch, and ¼ inch objectives, two pairs of eye-pieces, double mirror, and sundry odd fittings, complete in mahogany case, for £10 10s.

Stand only, without object-glasses or case, £8. It is also kept in in monocular form, at a proportionate reduction.



CROUCH'S 'HISTOLOGICAL' MICROSCOPE.

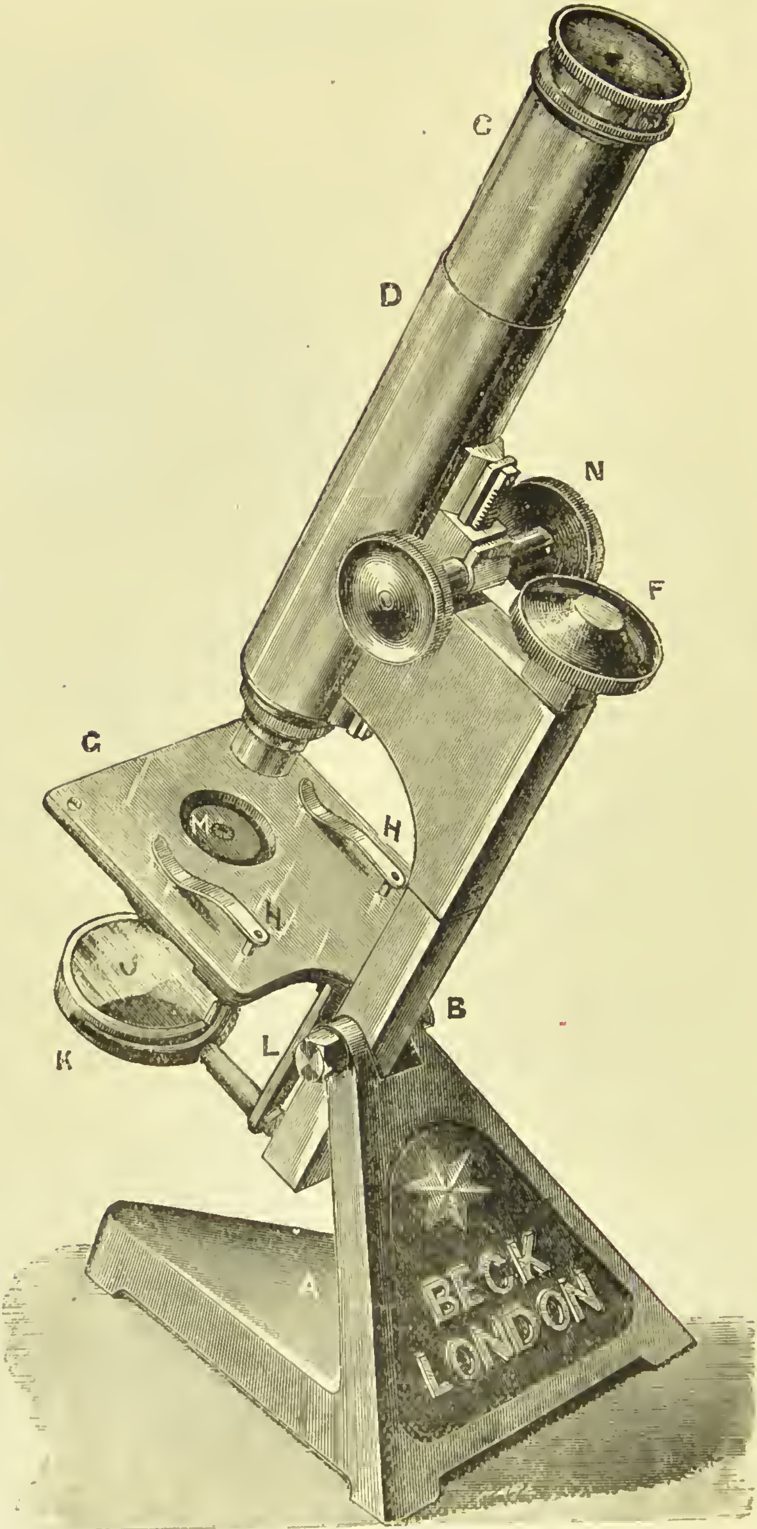
CROUCH'S 'HISTOLOGICAL' MICROSCOPE.

This stand is of very simple construction, but is capable of performing good work. It is provided with spiral rack and pinion coarse adjustment, in addition to a sliding movement in the cloth-lined body tube. The fine adjustment is of new construction, and extremely sensitive, being also quite free from lateral motion.

The stage is glass or brass, at the purchaser's option, and is provided with either a wheel or central diaphragm, as preferred.

This form of stand has been largely adopted by medical authorities as very suitable for students.

The price in mahogany case, with either a 1 inch and ⅔ inch, or ½ inch and ⅙ inch objectives, and two eye-pieces, is £7 7s.

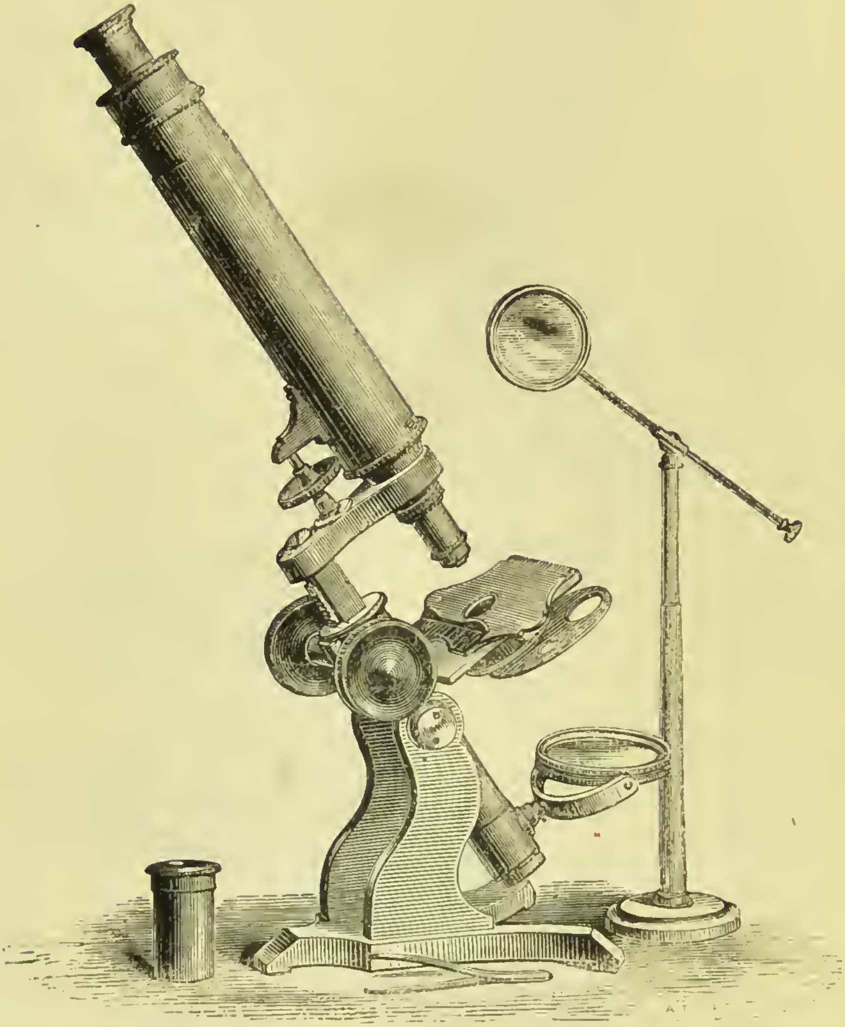


BECK'S 'STAR' MICROSCOPE.

BECK'S 'STAR' MICROSCOPE.

One of the newest and cheapest patterns adopted by its makers. Its details explain themselves in the engraving. It need only be specified that the base is of iron, and of a pattern which secures a maximum of stability at a very small cost. The rest of the stand is of brass, machine-made and nickel-plated, so as to resist the corrosive action of the atmosphere. The object-glasses are affixed by the universal screw, so that the owner of the stand may be free to use any objectives he may require. There is, in addition, an iris diaphragm. The fine adjustment is on a new principle, and combines great delicacy of movement with simplicity and economy.

This instrument, with 1 inch and ¼ inch object-glasses, costs £4 4s., in cloth-covered case; if in upright walnut case, with lock and handle, 7s. 6d. extra. A complete set of additional apparatus suited to the stand is also supplied *en masse* by the makers for £5 15s.



How's 'Students'' Microscope.

HOW'S 'STUDENTS'' MICROSCOPE.

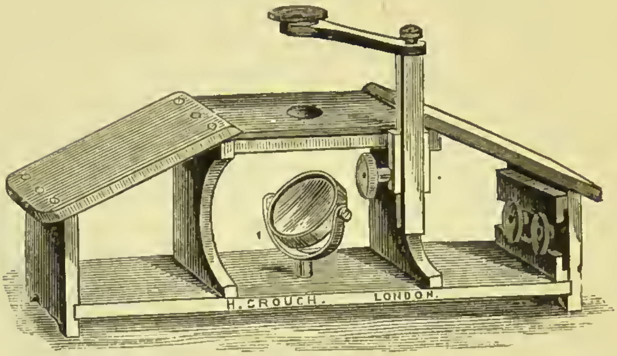
This is a working instrument of a very good class. The stand is of brass, and well finished. The body has both coarse and fine movements, and is fitted with a draw tube.

The arrangement of the stage and its object-holder is a very simple and convenient one, and not likely to get out of order.

The whole microscope has the merit of being one which was early brought out as efficient for all ordinary investigations, at a moderate price.

It is now supplied as figured, with a stand condenser and separating object-glass, giving powers 1 inch, ⅓ inch, and ¼ inch, complete in mahogany case, for £5 5s.

Separate object-glasses of excellent quality, of 1 inch and ¼ inch focus, can be substituted for the dividing power for £1 15s. extra.



DISSECTING MICROSCOPE.

It is often of great service to have a *simple*, steady magnifying instrument at hand, on which can be placed any object that requires dissection or manipulation before being placed under the more powerful compound instrument, and to have both hands free for use.

This desideratum is well supplied by the contrivance shown above, as devised by Mr. Crouch for Professor Huxley. It is so arranged that where necessary a body tube with eye-piece can be added, thus converting the simple form of microscope into the compound one. The whole is supplied complete by the makers, with two objectives, 1 inch and $\frac{1}{6}$ inch, and one eye-piece, for £7 7s. in mahogany case. Any low-power object-glasses might also be used with it.

NOTE.—It must be thoroughly understood that in selecting the previous instruments for illustration and description, the author does not intend to recommend them (or their makers) in preference to the many others of equally good quality, by the same or other manufacturers, which are in the market.

These microscopes have been chosen as representative types of the three classes of instruments to which it has been considered desirable that attention should be called.

Both more expensive and more complicated, and cheaper and more simple stands, are made by these and other opticians, from all of whom the purchaser may rely on obtaining an instrument thoroughly good and effective in proportion to the price paid for it.

CHAPTER V.

EYE-PIECES.

As already explained, in the description of the parts of a microscope, the eye-piece is that portion of the optical apparatus placed at the top of the tube nearest the eye of the observer (hence its designation). The form of eye-piece almost invariably used is called the Huyghenian; although, as its magnifying powers are always low, extreme perfection is not so essential as in the case of the object-glass, it is of much importance that great care be taken that it is highly polished, the glass of which it is composed free from all defects such as striæ, bubbles, etc., and the distance from each other of the two lenses which, when mounted in a brass tube, complete it, correctly calculated.

When it is understood that every imperfection of the object-glass is exaggerated in proportion to the power of the eye-piece used with it, the necessity of accuracy in the latter will be fully appreciated.

Eye-pieces are made of various powers, and are either designated by their makers A, B, C, etc., or 1, 2, 3, etc., the power increasing as the alphabet or numerals advance.

The most powerful eye-pieces are always shorter than those of lower capacity, as their lenses are of higher curvature and must be placed closer together. It may be here remarked that the lower power eye-pieces should be used wherever practicable, as the field of view is larger and the light much brighter ; it is also generally preferable to use a higher power object-glass with No. 1 eye-piece than a shorter focus objective with a higher, or 'deeper' as it is sometimes called, eye-piece, unless the object examined should be one necessitating considerable penetrating power—that is, one of appreciable *depth;* in this case the reverse would be the better course, in consequence of the greater 'penetration' found in the lower power object-glasses.

Very deep eye-pieces can rarely be used with satisfaction, unless expensive illuminating apparatus is employed below the stage.

Kellner's eye-piece is a variety intended to give a very large field for the examination of flat objects of some extent, with very low powers; but as it provides but poor definition of detail, it is seldom employed. An indicator—that is, a short arm of metal for pointing out an object or portion of one to an observer—is occasionally inserted in an eye-piece. It can be withdrawn when not in use, and the field of view left quite clear.

OBJECT-GLASSES.

The object-glass, or objective, as it is usually called, is the principal and most important optical portion of every microscope. It screws into the bottom of the body, and is the lens which forms the image of the object under examination; this image is again magnified by the eye-piece, and so presented to the eye of the observer.

As the objective is the prime producer of the image, it is of course absolutely necessary that its construction should be as perfect as human skill and science can make it. To this end have been applied the best efforts of mathematicians and opticians both in England, America, and Germany with the result that we have now object-glasses the perfection and power of which may be broadly stated as only limited by the purses of the purchasers.

Objectives are in this country and America designated by their focal distance from the object—thus a one-inch object-glass is one which gives the same magnifying power as would a *simple* plano-convex glass whose focus is one inch from the object in view, and so on in all other cases. As a matter of fact the 'working distance' of all microscope object-glasses is in nearly every case much less than would be implied by their nomenclature, as they are *compound* lenses, in some cases consisting of eight or twelve separate glasses mounted in varying combinations, and in consequence of this complexity focussing much closer to the object than a simple plano-convex glass. This definition is therefore to be only understood as an indication of the magnifying power of the objective.

Object-glasses are constructed from a four inch power magnifying ten diameters (in scientific estimations of magnification *diameter* and not superficial measurement is always to be understood) to the $\frac{1}{40}$ inch, which gives an amplification of 2,000 or so diameters, with the A or No. 1 eye-piece in both cases.

What may be considered as low powers include all powers up to the $\frac{1}{4}$ inch. with which a magnifying power of 200 may be obtained. All glasses of shorter focus may be properly classed as high powers, and in most cases, especially when using deep eye-pieces, it will be advantageous to employ some accessory illuminating apparatus with them, if the best results are wished for which they are capable of producing.

In the construction of an objective the 'angle of aperture' is a most important feature—briefly, this term signifies the extreme angle at which rays of the pencil of light from the object can enter the objective and form an image. As glasses of high angle usually consist of more lenses than those of smaller aperture, they are consequently much more expensive. The advantages of a high angle are great increase of brilliancy in the image, and much *resolving* power (or capability of separating very closely approximating lines); the drawbacks to an excess of aperture are a loss of *defining* power, that is, distinctness of the image, and the fact that the higher the angle, the closer does the front lens of the objective approach the object: this in the case of the highest powers is a very serious disadvantage.

As a rule the student would do well to limit himself to moderate angles, avoiding a cheap glass of small aperture which will only give him a dimly-lighted field, and at the same time falling short of the excessively high angles which are produced in what the author would call 'fighting' objectives; these, however, have their use and value in the hands of specialists, although, for the reasons stated, unsuitable for the general work of the average student. As an example of what is intended by a moderate aperture, 30° say for the one inch, and 90° for the $\frac{1}{4}$ inch, are ample for all ordinary objects suitable for examination by these powers, although some makers produce a one inch of 60° and a $\frac{1}{4}$ inch of 140°.

The qualities which should be found in well-constructed object-glasses, and for which they should be tested, are very ably and clearly described by the late Dr. Carpenter as follows: 1. Working distance; 2. Defining power; 3. Penetration; 4. Resolving power; 5. Flatness of field. A few remarks on each of these qualities may be of assistance to the student whose means are limited, and who consequently has to select his glasses with a view to the special work for which he intends them, more than one of each power he decides on purchasing not being within his reach.

WORKING DISTANCE.—This quality refers to the interval between the front lens of the objective and the object examined, when the latter is in proper focus. As already remarked, this is always much less than the nominal designation of the glass used; in the lower powers this is not of much consequence, as in lenses of one inch or lower power, there is usually plenty of room for the illumination of opaque objects from the side. In the cases of objectives of higher power, their uses are mostly for transparent objects, which are lighted by the mirror or other and additional contrivances below the stage, so that great working distance is not here an absolute necessity; still it is always an advantage, and in cases where a low angle of aperture is sufficient in the glass, a good working distance will be found of much convenience.

DEFINING POWER.—Perhaps the most important of all the necessities in an object-glass. The lack of it is shown by the inability of the lens to produce a well-defined image of the object with edges clear and undimmed by fog, haze, or colour. As, however, every maker referred to in this little manual may be relied upon to furnish glasses of exquisite definition, perhaps no more is necessary to be written on this head.

PENETRATION.—This quality must be understood as referring to the power of the glass to give a correct view of an object possessing an appreciable depth, *e.g.*, the ability of enabling the observer to see 'round' a *foraminifera*, or a seed, or 'into' the depth of such a section as that of human lung or liver, thus enabling him to trace the connection of vessels or tissue lying on different planes in the object. Penetration must on no account be confounded with resolving power, which will be next alluded to.

RESOLVING POWER is the capability of resolving or dividing the component parts of a minute object, such as the markings on the *Diatomaceæ*, the infinitely closely ruled lines of Nobert's Test Plate, or the 'exclamation marks' on the Podura scale. As a rule, resolving power in an object-glass is dependent on its angular aperture; a ¼ inch glass of 140° will separate lines not definable with a ¼ inch of 75°, under the same conditions of working. It will thus be seen that this quality is opposed to that of penetration, which is possessed by glasses of low or moderate aperture, and that the two requisites can only be combined in the same objective by some sacrifice of each. The purpose for which it is required must govern the student's choice of his 'powers.' A rough recommendation may be given to select high angles with powers above a ¼ of an inch, and moderate with those of longer focus.

FLATNESS OF FIELD is the last desideratum to be looked for in an object-glass, and the one of least importance: it is the power of showing the whole of a large flat object in correct focus at once, even to the extreme margin of the field of view; it is of the most importance in the lower powers with which such objects are usually examined. In the case of glasses of short focus, as the $\frac{1}{4}$ inch or higher power, the object is usually a minute one, which is in nearly all cases placed in the centre of the field ; and if in the margin of it, the slight alteration of focus necessary causes little trouble.

Since the introduction of 'the immersion system' for glasses of high power, in which the front lens of the objective is temporarily united to the cover-glass of the objective by a drop of either oil or water, a great stride has been made; glasses of higher angle can be more conveniently used than before, as the working distance is greatly increased; more light enters the object, and both the resolving and defining power of glasses has been much augmented.

Object-glasses of high power and most finished construction are generally provided with an adjustment to compensate for the thickness of the covering glass of a mounted object: this consists of a graduated screw collar, which alters the distance between the front and posterior combinations of lenses. Messrs. Beck give the following concise directions how to make this compensation effectually :

'Turn the collar in the direction of the arrow till it stops; the O will coincide with a line on the tube of the object-glass, which is then adjusted for an uncovered object.

'Turn the collar back to where the best definition is observed. This position will vary according to the thickness of the covering-glass ; if this is $\frac{1}{1000}$ of an inch thick, 1 will be the proper adjustment ; if $\frac{7}{1000}$, 7 divisions.

'For medium thin glass about 6 divisions will be found very nearly correct.'

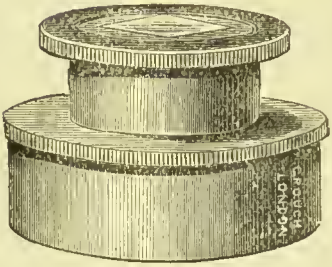
The author would advise the student who wishes to go into the theory of angular and numerical aperture to peruse pp. 850 to 854 of 'The Microscope and its Revelations,' in which Professor Abbé's discoveries and views of this interesting department of optical theory are stated as concisely and lucidly as possible. It would be foreign to the plan of this volume to introduce this somewhat abstruse subject here.

TABLE OF APPROXIMATE MAGNIFYING POWER OF OBJECT-GLASSES, WITH VARIOUS EYE-PIECES.

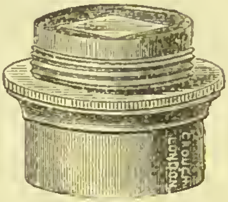
Object Glasses.	Eye-pieces.			
	No. 1.	No. 2.	No. 3.	No. 4.
4 in.	10	15	25	35
3 in.	13	20	35	50
2 in.	20	35	60	90
1½ in.	30	45	80	120
1 in.	50	85	120	170
⅔ in.	60	105	180	270
½ in.	100	180	330	440
$\frac{4}{10}$ in.	130	235	410	500
¼ in.	250	400	610	720
⅕ in.	275	450	720	900
⅙ in.	433	614	870	1102
⅛ in.	480	620	980	1200
$\frac{1}{10}$ in.	540	850	1300	1890
$\frac{1}{15}$ in.	750	1220	1910	2730
$\frac{1}{20}$ in.	900	1650	2310	3540
$\frac{1}{40}$ in.	2000	3200	6000	8000

CHAPTER VI.

ACCESSORY APPARATUS.



Polarizing Prism.



Analyzing Prism.

The Polariscope.

The apparatus, as used with the microscope, for exhibiting the beautiful and instructive effects of polarized light, consists of two parts, the polarizer and the analyzer.

These two instruments may both, or either of them, be composed of a naturally formed rhombohedron of Iceland spar, artificially bisected, and cemented together again in its original position—this process throws one of the transmitted rays out of the field of view, and it becomes a single-image, or 'Nicol' prism—or of a thin plate of precious stone called tourmaline, cut in a plane parallel to its optic axis.

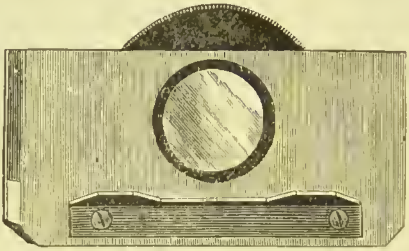
The polarizer is the 'producer' of the phenomenon of polarized light, and must be inserted below the object to be examined, so that the light transmitted through it shall be polarized—it is for this purpose placed in the fitting below the stage, or in that of the sub-stage, should the instrument be furnished with one. The analyzer is the 'examiner' of the light, and must either be screwed into the lower part of the tube above the object-glass, or be placed over the eye-glass of the eye-piece, as may be found most convenient: in the former position it has the advantage of giving a large field, but even with a prism of finest quality and largest size, some loss of light can be perceived; while in the latter, the field of view is somewhat restricted, but a bright and vivid image is ensured.

Nicol prisms are almost universally in use for both polarizer and analyzer, good tourmalines being very expensive, and moreover nearly always communicating some colour to the 'field.' The author can, however, speak very highly of the convenience of having a pale-tinted tourmaline mounted as a cap for the eye-piece, and so fitted as to bring the plate very close to the eye-glass; by this method but small reduction in the field of view is made, and in cases where the length of coarse adjustment of the microscope is limited, it is frequently of importance to save the space occupied by the prism when inserted above the object-glass.

The polariscope, as above described, will by itself reveal many peculiarities of structure in a variety of objects, but to observe the gorgeous colour-effects which are so striking a feature, it is necessary in most cases to employ a plate of a mineral called selenite on the stage below the object.

Selenite is a crystal of hydrated sulphate of lime, which splits naturally and easily into thin plates; the thickness of these plates determines the colour communicated to the object, each plate when split or ground perfectly plane giving the complementary colours of red and green, or blue and yellow, or some modification of the same. If not split evenly the colours are 'patchworky,' and the plate is useless for scientific purposes.

All leading opticians keep mounted selenites ready for sale, and several ingenious devices have been employed to render their use easy, and application exact.



The above engraving represent's Siddal's Mica Selenite Stage, as manufactured by Mr. Crouch; it can be used with any ordinary mounted selenite, and the rotation of the mica film provides an endless variety of colour and tint.

Both polarizer and analyzer should be so mounted as to rotate, and if the stage of the microscope also revolves it will be of additional service, as a different class of effect is produced by the rotation of the object between the two parts of the polariscope and the revolution of either portion of the latter.

When the axes of the polarizer and analyzer are in the same plane, the field of view will be light; but when either is revolved the light gradually fades, till an angle of 45° is reached, when all is dark. On proceeding with the rotation the light reappears, and disappears again at each quadrant; and the same effect will be produced with the complementary colours if a plate of selenite is on the stage.

This test will satisfy the observer whether the apparatus is properly constructed.

Polarized light is especially useful for the examination of rocks, minerals, starches, chemical crystals, scales, hair, horn, and fibres.

THE ACHROMATIC CONDENSER.

The achromatic condenser is, as its name implies, a combination of lenses perfectly achromatic, in a special mounting, which is interposed between the mirror and the object-glass, greatly improving the performance of the latter when powers of $\frac{1}{4}$ inch or shorter focus are in use on transparent objects. It is placed in the sub-stage when the microscope is provided with one, or, if this fitting is wanting, it slides into the circular tube beneath the main-stage, and is then raised or lowered by the hand.

The achromatic condenser is usually furnished with one or two wheels providing various apertures, and also different 'stops' for the supply of oblique light, which is so necessary for the 'resolution' of minute markings on test objects. The apertures and stops can individually, and in any desired combination, be brought central to the optic axis; and in this case the apertures limit the marginal portion of the rays of light, and the stops cut off the central, thereby permitting the transmission of light from any part of the system of lenses composing the condenser that may be desired.

When an intensification of the light only is desired, without more obliquity than can be obtained by the manipulation of the mirror alone, one of the ordinary objectives makes a very perfect condenser when screwed into an 'adapter,' which can be carried by the sub-stage.

In small instruments, the spot lens (to be afterwards described) makes a fairly efficient oblique illuminator when high powers are in use; for this purpose it should be of tolerably high angle of aperture.

As an accessory for the production of very oblique light, the 'oil immersion illuminator' of Messrs. Watson and Sons may be highly spoken of. It consists of a plate of vulcanite, in the centre of which is set a small plano-convex lens. It is used on the stage with the plane side uppermost; on the lens is placed a drop of cedar or castor oil, and the slide containing the object is superposed on this. Light is then thrown from the mirror through the 'illuminator,' which transmits it to the objective at a much greater angle than the latter would receive it through an air medium.

THE PARABOLIC ILLUMINATOR AND SPOT LENS.

These are two contrivances for the performance of the same office, namely, the illumination of a transparent object not by the rays of light passing through it, but by light reflected from itself. The parabolic illuminator is the most perfect of the two forms, and consists of a paraboloid of glass set in a brass fitting for the sub-stage, having its top ground out to a spherical curve, on the bottom of which a black central stop is placed.

When the rays of light from the mirror pass through this paraboloid, and it is properly focussed with relation to the object on the stage, none of them can pass through the object, but all come to a focus at a point immediately above it : the field of view then appears completely dark, and many objects are shown very superbly, by as it were their own light, like stars on a dark sky.

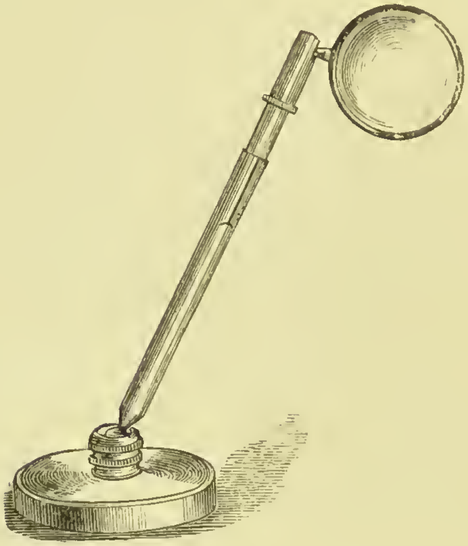
This kind of illumination is very effective for such objects as small *foraminifera*, scales, bone, teeth, hairs, and diatoms when mounted as dry transparent objects ; it is also of service in the examination of many geological sections.

THE SPOT LENS.—This is a cheaper piece of apparatus for producing a similar effect. It consists of a (generally) hemispherical lens in a brass tube, with a black spot in the centre. It is used in the same way as the paraboloid, but as it is of longer focus, it cannot be used with objectives of such high power as can the latter ; but with glasses of one inch or longer focus it forms a most efficient substitute, and no microscope can be considered complete which does not possess one or other of these accessories.

THE BULL'S-EYE CONDENSER.

This very useful adjunct consists of a plano-convex lens of glass mounted on a stand, with various mechanical movements provided for.

Its chief use is for the illumination of opaque objects, for which it is indispensable both by day and lamp-light.

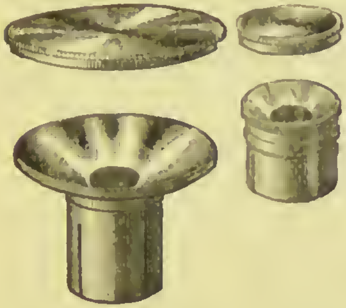


The plane surface is turned towards the source of light, and the lens is then raised or lowered by the aid of its sliding tubes, and turned round upon its top fitting until a suitably bright light is thrown upon the object: a little practice is necessary for obtaining the best result possible from its use.

The condenser is also useful for intensifying the light upon the mirror, when necessary, while examining transparent objects by *artificial* light; in this case the convex side is turned to the lamp, and the parallel rays proceeding from the plane side thrown upon the mirror. Its aid under these circumstances will be found very valuable if care be taken as to the relative distances of lamp, condenser, and mirror.

Stand condensers are made of various sizes and prices by the different opticians, and are also constructed to fit into some part of the stage of the smaller microscopes; but this is not by any means so convenient an arrangement as to have them mounted on a separate stand.

The Lieberkühn and Side Reflector.

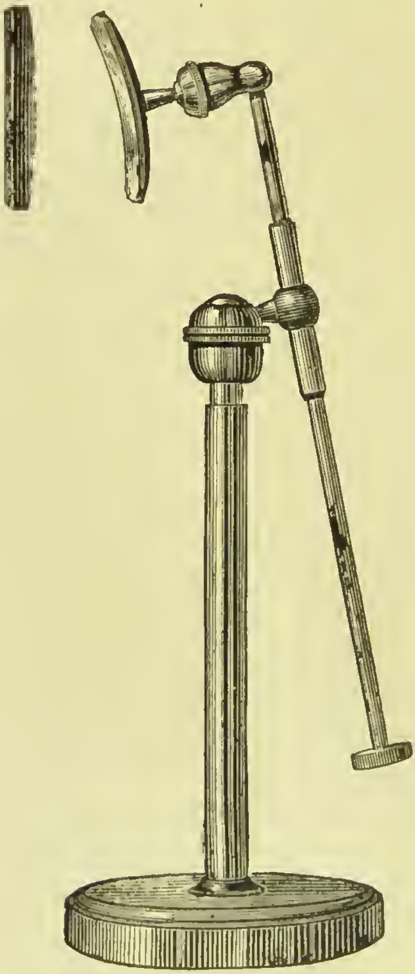


These are very important aids to the proper illumination of some opaque objects. The Lieberkühn consists of a concave circular speculum mounted on a short piece of brass tube, which slides over the mount of the object glass, and reflects the rays of light from the mirror which have passed up *around* the object and impinged upon it, back upon the object, which is thus most brilliantly lighted up.

It is obvious, as different objectives focus at varying distances from the object, that it is necessary to have a separate Lieberkühn for each glass, as the perfection of illumination can only be obtained when the curve of the speculum is adapted to the focal distance of the object glass. This consideration, and the fact that objects on which it can be advantageously used must be mounted in a special manner, that is, on an opaque disk, which freely permits the passage of the rays of light from the mirror all round it, have caused this piece of apparatus to be in less request than, from its very excellent results, it deserves to be. Any quantity of 'shade' that a large opaque object may require for definition of its details may be supplied by a slight indication of the mirror, and whenever the Lieberkühn is in use, the stand condenser (when working by lamplight) should also be employed, as described under its own heading, for intensifying and concentrating the light on the mirror. A set of 'dark wells' is often supplied by opticians to use with the Lieberkühns. These consist usually of

3 cup-shaped stops of various diameters, each mounted on a short pin, fitted so as to come under the centre of the object under examination: they are intended to effectually prevent the passage of light *through* the object when it is not mounted as opaque, or when the disk on which it is situated is not of as large diameter as the front lens of the objective.

THE SIDE REFLECTOR.—To obviate the difficulties mentioned above in the use of the Lieberkühn, this very useful piece of apparatus was invented.



It consists practically of what may be termed a *segment* of a Lieberkühn, and is variously mounted for use; it is sometimes placed on a stand in the same fashion as the stand condenser, but more frequently mounted on a short arm, for which a fitting is provided in the limb of the microscope. A cover is usually furnished to preserve the highly polished silver surface.

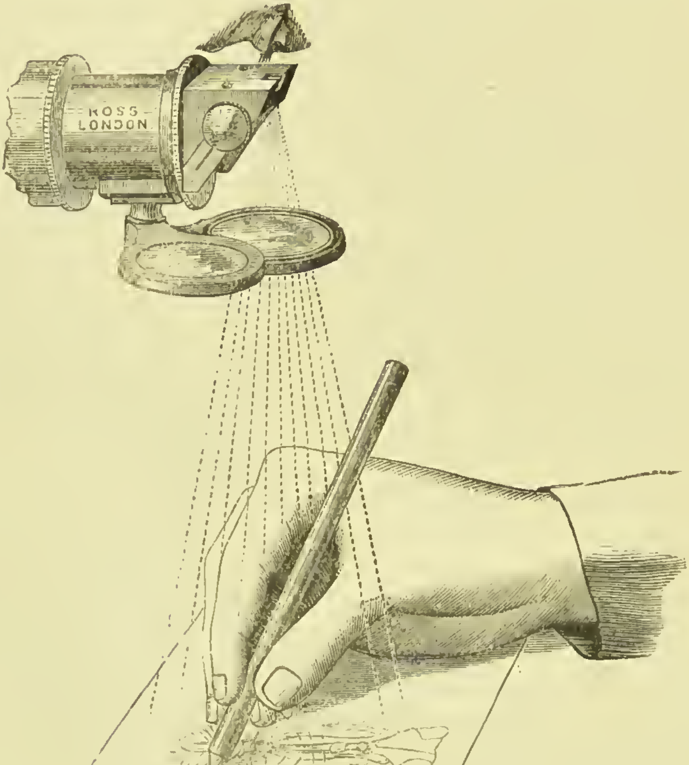
When used by daylight, no condenser is necessary, but by artificial light the latter is very useful, and will, when placed between the lamp and the reflector, condense the rays from the lamp upon it, and produce an illumination which is sometimes dazzling. This reflector can be used with any object glass from the ½ inch downwards, and can be employed on any opaque object, however mounted, even in the deep cell of a wooden slide.

Its universal motions enable the observer to use it with much facility, and the author must express the opinion that it supplies by far the best mode of illuminating an opaque object by daylight with which he is acquainted. When the short arm has been fitted into the stand, the reflector has to be brought into position between the objective and the object, and moved about until the rays from the window or the lamp fall with brilliancy upon the latter. A very little practice will ensure the most satisfactory results.

THE CAMERA LUCIDA.

This instrument in the form illustrated consists of a prism in an appropriate mounting which is placed over the top of the eye-piece, the usual cap which covers it having been first removed. The microscope should be then placed in an horizontal position, and if necessary raised so that the prism may be, as nearly as possible, 10 inches above the table.

If the eye is then applied above the prism, as indicated in the engraving, an image of any object in focus will be observed on a sheet of paper placed upon the table beneath. Some little practice will enable the observer to see the image of the point of a pencil or pen at the same time, and an outline drawing of the object can be made with a rapidity and accuracy quite astonishing to an onlooker. It must be understood, that little more than an outline is attainable by this means, and that all detail and finish to the drawing must be filled in according to the skill of the artist, as in the case of an ordinary drawing.



A simpler piece of apparatus for the same result is the 'neutral tint reflector' of Dr. Beale. This is composed of a plate of neutral coloured glass fitted at an angle of 45° in a cap which fits over the eye-piece precisely as in the more expensive form above shown. It is managed in the same manner, and the author can confidently recommend it as thoroughly efficient and answering every purpose.

THE MICROMETER.

The microscopist frequently desires to ascertain the exact size of an object under examination : for this purpose a micrometer is necessary. The stage micrometer is a glass slip in the centre of which are ruled 10 or 11 fine lines the 100th of an inch apart ; one of the divisions is again divided into ten, thus supplying intervals of $\frac{1}{1000}$ of an inch. The eye-piece micrometer is a circle of glass which is placed in the eye-piece, and rests on the diaphragm which is inside it ; it must be in the correct focus of the eye-glass. This circle is ruled with a series of lines at equal distances, but which need not be very close together. The use is as follows ; the stage micrometer having been focussed as an ordinary object, the 'value ' of the divisions in the eye-piece, with the objective in use, can be at once ascertained : the stage micrometer having been removed, any object placed on the stage can be at once measured by the divisions in the eye-piece micrometer, which appear to be placed over it in the same manner as an ordinary rule. The 'value' of the eye-piece divisions of course varies with the power of each object-glass used ; when once ascertained, a register can be kept and referred to, which will save time and the necessity of a fresh calculation.

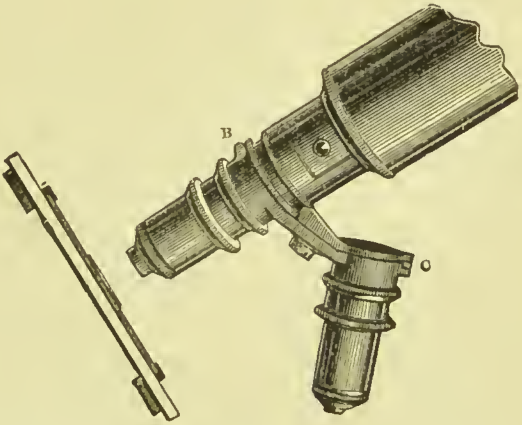
An even more accurate method is to place the microscope horizontally, apply the camera lucida, trace the outline, or dimension, of the object on the paper, and then do the same by the divisions of the stage micrometer, below it: its size will then be apparent at a glance; in this operation the eye-piece micrometer is not needed.

The exact magnifying powers of an objective with any eye-piece can be most readily ascertained by the latter method.

It is obvious that if the 'hundredth' divisions of the stage micrometer, as traced on the paper, correspond with one inch on an ordinary rule, the magnifying power is 100 diameters, if they extend to $\frac{3}{4}$ inch only, the enlargement is 75 diameters, and so on.

THE NOSEPIECE.

This is a handy piece of apparatus which furnishes a ready means of substituting one object-glass for another without the trouble and loss of time necessitated by unscrewing one and inserting another. It consists of a bent plate, which is screwed on to the nose of the microscope, as shown in the engraving, with two or more arms in which may be screwed at



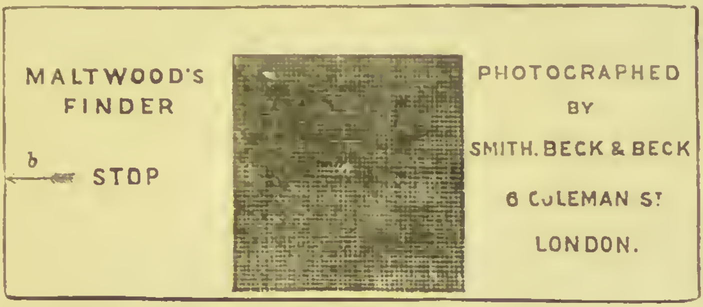
the beginning of the sitting whatever glasses may be likely to be called into requisition.

The rotation of the nosepiece will bring either, at pleasure, into use in its proper position, while the bent form of the arm carries the glass or glasses not in use out of the way of the stage.

The *double* form is shown in the illustration, but some makers produce them to carry three or four objectives at once; in this case, however, the weight of the accessory is a great drawback, and must tend to strain any fine adjustment when the latter is so arranged by the maker as to act on the nose of the instrument. To obviate the objection of weight, Messrs. Beck produce the nosepiece in aluminium, but in this metal it is necessarily an expensive luxury.

Maltwood's Finder.

One of the most wearisome tasks of the microscopist is the search for a minute object, under a high power, on a slide which he knows contains it, but which owing to the want of knowledge as to whether his glass is in exact focus for the plane on which it is situate, and of its precise whereabouts, frequently



taxes his time and patience to the utmost, before he finds it.

A very effective piece of apparatus was designed by Mr. Maltwood to assist the observer in this difficulty. It consists of a glass plate, rather larger than the usual 3 × 1 inch slips, on which is affixed a photographic rectangle containing 2,500 squares, each containing two numbers, one serving as a 'latitude,' the other as a 'longitude.' The left hand of the plate being always placed against a 'stop,' or flush with the edge of the stage, it is used thus: a slide of strewn diatoms, say, containing a particular form to which reference will have to be made, is placed on the stage; the valve in question is found in the ordinary mode and placed in the centre of the field: the slide is then removed, and the Maltwood Finder substituted for it, note is then made of the two numbers in the square most central in the field.

When next the diatom is wanted, the Finder is placed first under the glass, the numbers registered are found without any trouble, and if the strewn slide is placed in the same position as the Finder occupied, the particular valve will be found in the field of view after any difference of focus necessary has been effected.

THE SAFETY STAGE.

Several devices have been brought into use with a view of avoiding the risk of breaking either the front lens of the objective or the covering glass of an object (which may possibly be very expensive, and otherwise difficult to replace), when working with very high powers.

In many cases glasses of high angular aperture and of very short focus approximate so nearly to the cover glass of an object before the correct focus is obtained, that it is next to impossible for the observer whose attention is directed to the field of view, to know what the working distance is, and a very slight movement of even the fine adjustment will send his object-glass crashing through the cover of the slide, to the possible ruin of both.

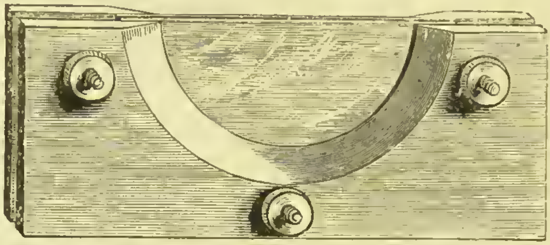
Some of these plans are complicated and rather expensive, but the author would draw attention to a cheap and effective safety stage supplied by Messrs. Watson. It consists of a plate of vulcanite, on which are fixed two slight springs of brass: the object is placed upon these, and they press it upwards until it rests against the screws on the top of small brass pillars. The slide is thus kept perfectly steady under any power, and all danger of accident is removed, as the tender brass springs yield with the slightest pressure of the object-glass if the correct focus is overrun, and even the thinnest covering glass is perfectly safe from fracture. The very wide aperture in the bottom of this safety stage permits of the employment of extremely oblique light, when test objects are being worked upon.

TROUGHS AND LIVE-BOXES.

When examining living objects in water, or otherwise, some provision must be made for the retention of the fluid, or the confinement of the living specimen.

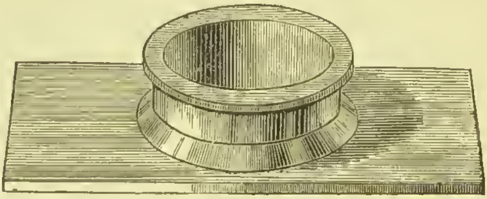
A trough, or live-box, is usually used for this purpose: either may be procured of most opticians of almost any desired size or price. One of the most convenient troughs is that contrived by Mr. Botterill, of which an illustration is given.

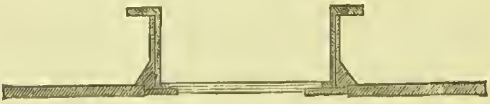
It consists of two brass plates bolted together, as shown, the plates of glass being separated, according to the depth of trough required, by an ordinary india-rubber ring of any thickness preferred. The whole can thus be taken apart and the glasses cleaned, or a broken front replaced without the trouble of cementing.



Botterill's Trough.

The ordinary live-box is figured here both in elevation and section. It is made as a brass plate with circular aperture, in which a brass tube is fixed having a glass cover, a short piece of tube, also with a glass cap, is made to slide over this, so that a small quantity of water, with any living objects in it, or a small live insect, can be very conveniently held between the





two glass surfaces, and submitted to any desired amount of compression.

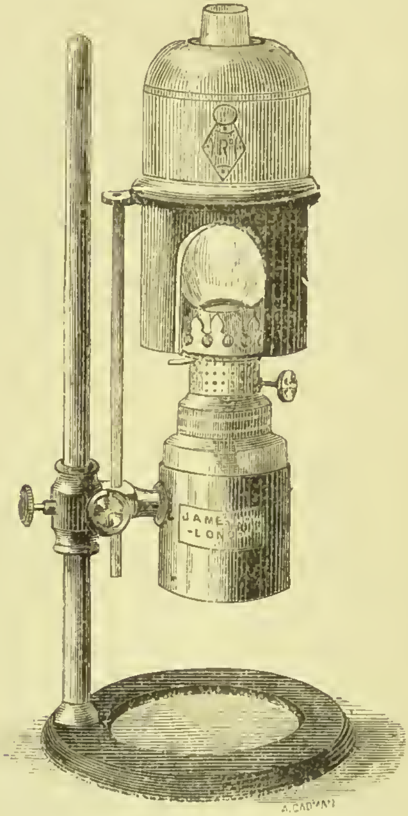
Useful substitutes for the above, and which will be found handy for many other purposes, may be provided by ordinary three by one inch glass slips, having an oval or circular cell, ground as a hollow in their centre: any shallow object in water or other medium can be dropped into the depression, and a covering glass placed over it will keep all in position by capillary attraction, even when on the inclined stage of the microscope. Several such 'hollow slips' will be found an inexpensive and most serviceable addition to the student's stock of apparatus.

THE LAMP.

This is one of the absolute essentials to the microscopist, as it is the fountain of all his light when using his instrument otherwise than by daylight.

A very excellent form of lamp, to burn paraffin, is that constructed by Messrs. How, and here figured.

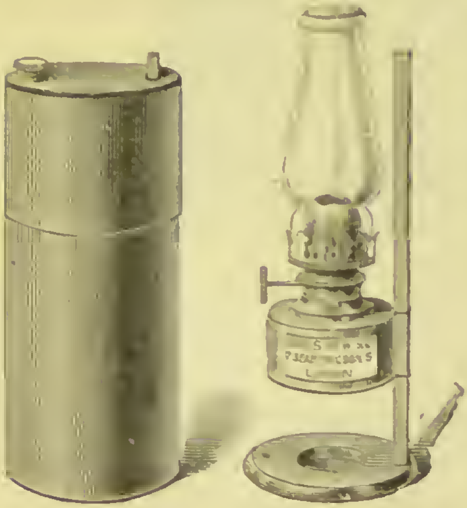
It is fitted with Hailes's porcelain shade, and has all necessary adjustments; the glass reservoir is protected by a brass case, from which it can be readily removed and in which it rotates, so that either the edge or flat side of the flame can be turned towards the opening of the shade. The shade can be adjusted to its proper height in relation to the flame, and clamped in that position by means of the screw facing the observer; the whole can then be moved up or down upon the pillar, and fixed at the required height by the screw shown on the left without deranging the adjustment of the shade. The lamp mount is hinged, so that the gallery, etc., may



be turned back to facilitate the cutting and trimming of the wick.

Lamps may be procured of many descriptions and sizes from the opticians; an illustration is given of a very handy and portable form supplied by Mr. Crouch, which although small, will yet supply most of the requirements of the observer.

The most portable lamp yet brought before the public is Messrs. How's 'Pocket Lamp.' As shown in the illustration, it fits into a cylindrical case for the pocket, and then weighs but twelve ounces. It gives ample illumination, and possesses all necessary adjustments; it is constructed to carry oil sufficient for three and a half hours' consumption.

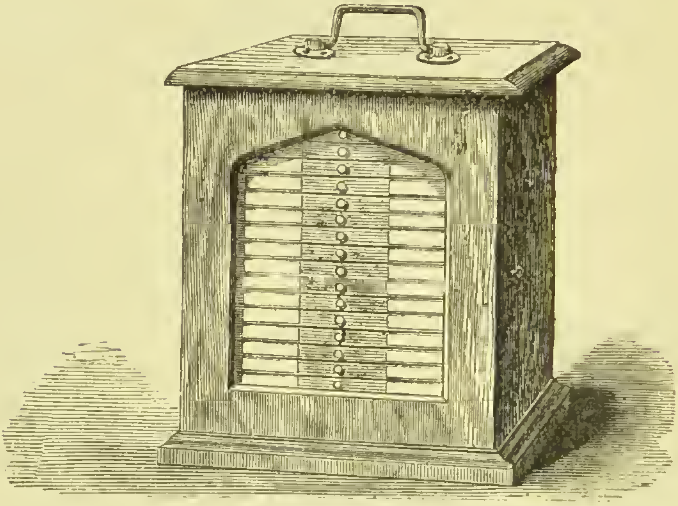


How's Portable Lamp.

When lamp-light is in use for the illumination of transparent objects, the mirror should be placed at such an angle and at such a distance from the stage that no reflection from its upper surface is visible. The neglect of this precaution will cause the field to shine with a glassy appearance, which spoils good definition, and is unpleasant to the observer.

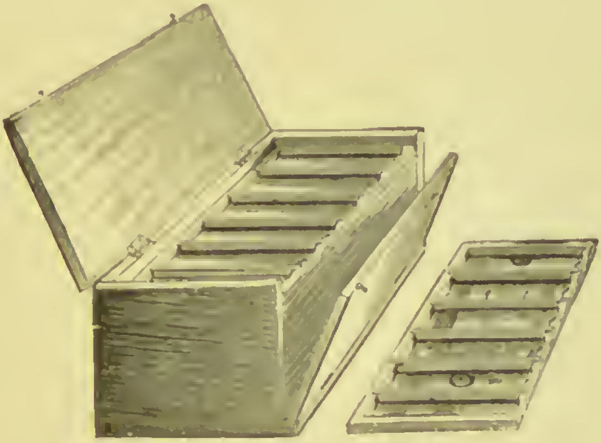
CHAPTER VII.

CABINETS AND CASES FOR OBJECTS.



THE student who takes up microscopical pursuits enthusiastically will quickly find himself under the necessity of providing a suitable receptacle for the mounted objects which he may either purchase or prepare himself. Cabinets of various sizes and materials are to be bought at all opticians'; they are made to contain from 200 to 1,000 objects mounted on the standard sized slips. But small difficulty will be experienced in procuring whatever is suitable to the requirements and the means of the purchaser.

While a cabinet is almost a necessity for the properly arranged and catalogued series of objects of the microscopist, it will be found of great convenience to provide a number of cases of the pattern shown in the illustration. These are made of various capacities, to hold from one to six dozen objects in a flat position. These very portable receptacles have many advantages: the objects not only lie horizontally, but each is separated from its fellow by a parallel division, so that all slipping over each other, and consequent risk of damage, is entirely obviated. The smaller sizes can be conveniently carried in the pocket of an overcoat, enabling the travelling exhibitor to transport his specimens safely to a soirée, or house of a friend; while the larger sizes (say of twelve trays, each to take six slides) might well be utilized each to contain a section, or portion of a section, of a large classified collection. These cases are sold either in pine or mahogany at prices varying from 1s. 6d. to 7s. 6d. The author can speak very



highly of the workmanship and finish of some 'six dozen' cases he has procured from Mr. Stanley. These are made externally of polished mahogany, but the trays are of pine; they are sold at the very moderate price of 5s. each.

CASES AND CABINETS FOR MICROSCOPES.

The smaller sized instruments are usually sold complete, with whatever accessories are furnished with them, already packed in a mahogany case; but, with the larger and more expensive stands, the case or cabinet is usually a separate matter, and is made for the purchaser to order, according to the quantity of apparatus he may purchase with the instrument, or may intend to add to it in the future.

In the latter case, he will do well to have provision made and space left for all the more important accessories, as he can then buy them at any time, and need not return the case to the makers for alteration. The ingenuity and skill with which our leading makers 'pack' a large quantity of apparatus in a very limited space is worthy of great admiration; when the various articles are taken out and laid on the table, it would appear almost impossible that the case could contain them.

It is usually advisable to have distinct and separate cases for the microscope, and for mounted objects; but in instances where cost is of no object, a very elaborate and handsome piece of furniture can be arranged for, by a glass-fronted case in the centre for the microscope and its appurtenances, and a large cabinet on each side of it for objects, all made in one piece.

REVOLVING TABLE.

This is a *luxury* which will be duly appreciated by those who can afford it. It consists of a solid and substantial table, large enough to hold both microscope and lamp, which revolves on an iron centre, and so enables two or three observers to obtain views of the same object without the great disadvantage of perpetually rising up and sitting down: they can sit round the table, and the microscope and lamp *in situ* come round to each in turn.

PRACTICAL HINTS TO THE STUDENT.

When examining any object for the first time, commence its investigation with an objective of low power, thoroughly learn all that that power will show you, and then proceed to use glasses of shorter focus, until you reach the highest that can be used on the particular object: you will thus 'build up,' as it were, a knowledge of the subject you are viewing, obtainable in no other way.

Until some experience has been gained in the use of high powers, it will be safer to use a low power in the first instance, to act as a 'finder' of the object, rather than to endanger the safety of the front lens of your object-glass, or the covering-glass of your specimen for examination. When the object searched for has been found under the low-power, and placed in the centre of the field, the high power glass can be substituted, and the object will then be included in the field, when it is properly focussed.

When examining test objects by lamplight, always turn the flame of your lamp *thin edge towards* the mirror.

It will be found more convenient, whether working by daylight or lamplight, whenever practicable, always to have the source of light on the left hand; the hands, when manipulating either the object, stage motions, or sub-stage apparatus, do not then interfere with the illumination of the object.

The highest power that can be advantageously used with the binocular arrangement is the $\frac{1}{2}$ inch, and the angle of aperture of this glass should not exceed 40°; it is of great importance also that its posterior lens should approximate as closely as possible to the Wenham prism; for this reason a short mount is to be preferred for this particular power.

If the student commences the pursuit with a moderate sized instrument, it will probably be, in some respects, to his advantage. He will be likely in this case to acquire an amount of manual dexterity which will be of good service to him, as he will be compelled to perform many delicate adjustments and movements to a nicety with his fingers alone, which in larger and more complicated instruments would be provided for mechanically, and the hands would therefore not receive the training necessary for an accomplished manipulator.

Should specks show themselves in the field of view, they are most probably caused by particles of dust in or on the eye-piece (this may be determined by revolving the latter, when, if, as supposed, the dust is here, it will also rotate); it may possibly be sufficient to remove the cap and polish the upper surface of the eye-glass with a piece of soft wash leather, or perform the same office to the lower side of the field-glass ; if, however, this does not remove the eyesore in question, the field-glass may be unscrewed from its mount and both surfaces readily cleaned. This is one of the petty annoyances the beginner always feels, but it may be here remarked that it is of slight importance, and that it is better not, too often, to clean the optical portion of a microscope : the experienced observer whose whole attention is absorbed by the *object* never sees such specks or spots unless they are of abnormal dimensions.

The wash leather used for cleaning both glass and brass should be of the softest and finest quality, and be kept for that purpose alone ; when bought new it usually contains dusty particles which should be thoroughly removed by beating. The leather should be kept in the microscope case, or in a separate closed box.

When using a monocular instrument, it is a good plan to keep *both* eyes open : a very little practice will enable the observer to *see* with only the eye above the tube, whichever that may be, and it is also beneficial to the sight to accustom one's self to use both eyes alternately.

Always make it a rule when you are not using an objective, but do not wish to replace it in its box, to stand it upright on the table, with the front lens uppermost : this will prevent an accumulation of dust on the back combination.

When changing one power for another on the microscope (the double nose-piece not being in use) always withdraw the glass considerably out of focus, by the coarse adjustment; this precaution saves all risk of damage to the objective or the object, and the neglect of it may be the cause of very considerable annoyance and expense.

When removing a mounted object from the stage, never lift it up, but always *slide* it off. If this operation is invariably performed by the left hand, it will avoid all chance of contact with the milled heads of the mechanical stage should the instrument be furnished with such.

Avoid too much glare from the lamp when examining transparent objects with low powers (an excess of light is fatal to the most perfect definition); and, whatever power is in use, whenever the microscope is employed, the less light in the room (especially in the neighbourhood of the instrument), except what the observer is using, the better.

When large opaque objects are under examination, it is but seldom that too much light can be thrown upon them; in this case a great point is to secure proper light and *shade* on the object, that its relative parts may each obtain a proper illumination and be thrown into the requisite relief. This is especially necessary when working with the binocular microscope.

The binocular form of microscope is invaluable for the investigation of small objects of some appreciable 'depth,' and especially of those whose parts lie at different planes; the relation and connection of such parts can only be satisfactorily made out with the binocular, and the observer will do well to keep his finger on the fine adjustment, as much is to be learned while the objective is in transit, as it may be called, from one plane to another.

Books which may be advantageously consulted.

Beale	*How to Work with the Microscope.*
Carpenter	*The Microscope and its Revelations.*
Cole	*Microscopical Studies.*
Cook	*One Thousand Objects for the Microscope.*
	Rust, Smut, Mildew, and Mould.
Davies	*On Mounting Microscopic Objects.*
Davis	*Practical Microscopy.*
Griffith & Henfrey	*The Micrographic Dictionary.*
Hogg	*The Microscope, its History, etc.*
Hudson & Gosse	*The Rotifera: or, 'Wheel' Animalcules.*
Kent	*Manual of the Infusoria.*
Phin	*Practical Hints on the Microscope.*
Pritchard	*History of Infusoria.*
Quekett	*Practical Treatise on the Microscope.*
Ralfs	*Desmidiaceæ.*
Schmitz	*Atlas of the Diatomaceæ. (Descriptions in German.)*
Slack	*Marvels of Pond Life.*
Spottiswoode, W.	*On Polarized Light.*
Von Cotta	*Rocks Classified.*
Withes	*The Microscopist.*

Selected List of London Opticians

FROM WHOM RELIABLE MICROSCOPES MAY BE OBTAINED.

BAKER, C., 244, High Holborn.
BECK, R. and J., 68, Cornhill.
BROWNING, JOHN, 63, Strand.
COLLINS, C., 157, Great Portland Street.
COPPOCK, C., New Bond Street.
CROUCH, H., 66, Barbican.
HOW, J., and Co., 5, St. Bride Street.
PILLISCHER, New Bond Street.
POWELL and LELAND, 170, Euston Road.
ROSS and Co., 112, New Bond Street.
STANLEY, W. F., 13, Railway Approach, S.E.
SWIFT and SON, 81, Tottenham Court Road.
WATSON and SONS, 313, High Holborn.

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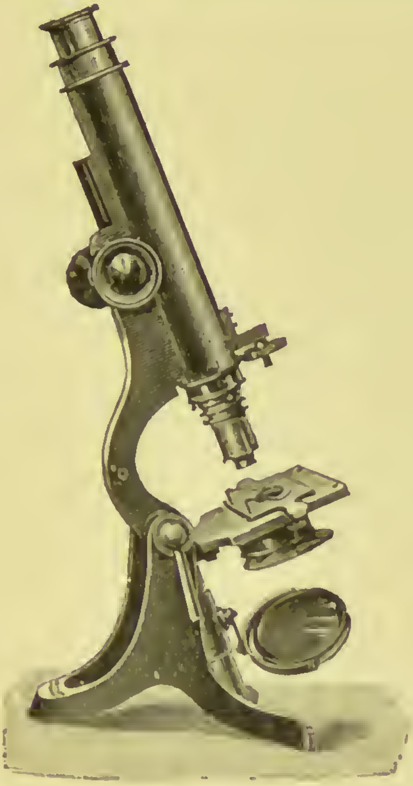

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